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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2.

VOL. 164—No. 4260 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, SEPTEMBER 19, 1947.* PRICE 1s. 6d. POSTAGE { INLAND 2½d. FOREIGN 3d.

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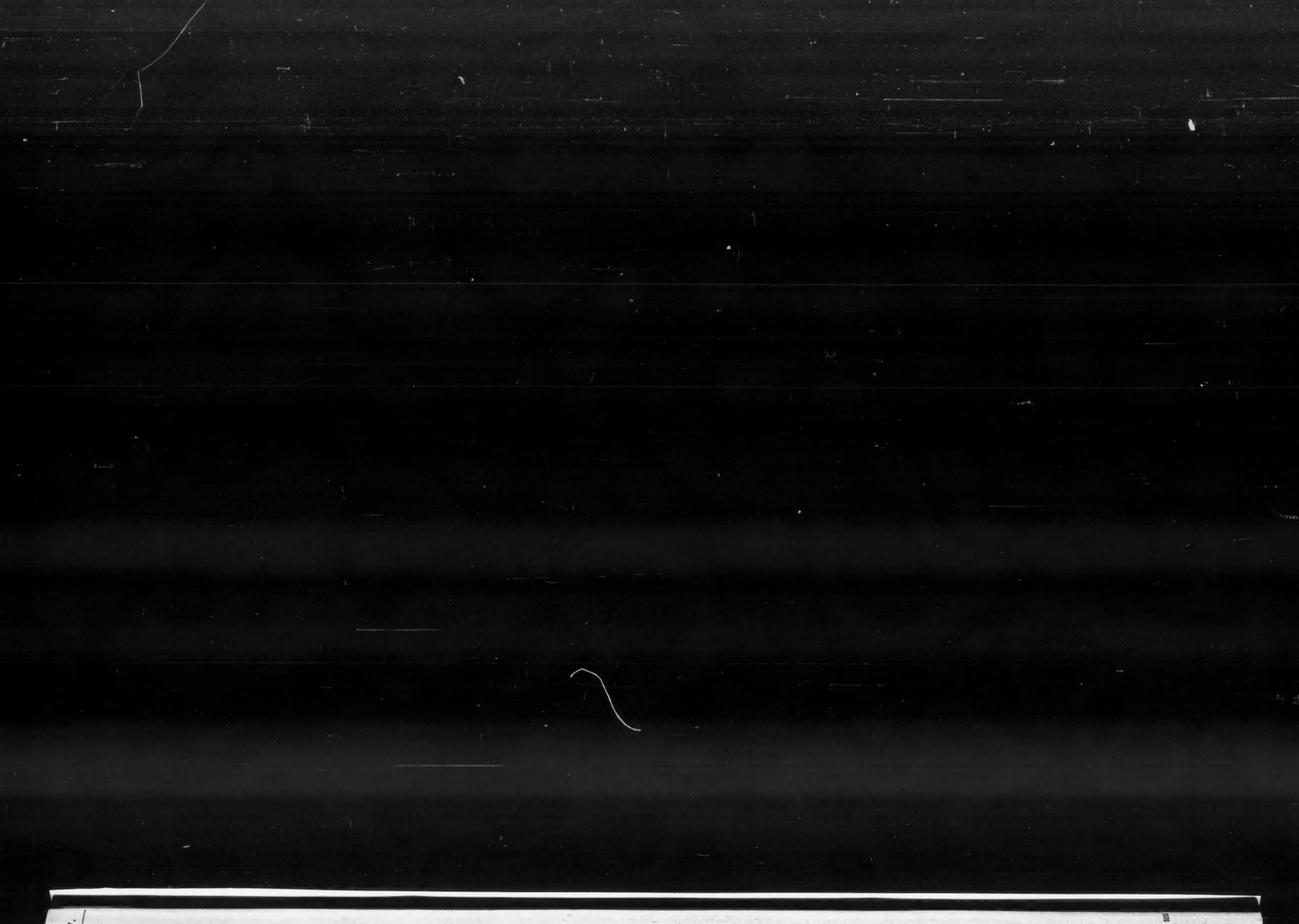
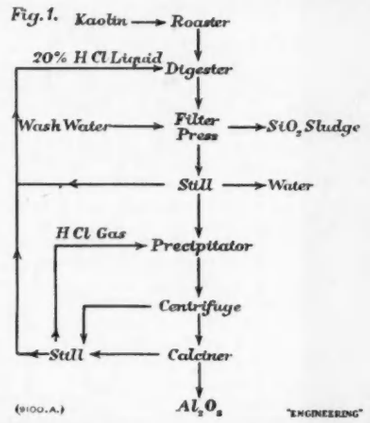


THE EXTRACTION OF ALUMINIUM FROM CLAY.

"THE manufacture of aluminum from clay will in the near future be imperative for the protection of the United States from dependence upon foreign sources of aluminum ore. According to Interior Department estimates, 70 per cent. of the supply of domestic bauxite has already been consumed. Under normal consumption, it is calculated, there is sufficient bauxite in this country to last only nine years. Because of the limited domestic supplies of low-silica bauxite, about 70 per cent. of the needs of the United States aluminum industry was being imported long before our entry into World War II." This statement is quoted from a document which has been circulated by the National Bureau of Standards of the United States. At a time when opinion almost throughout the world is concerned with the one-sided nature of the trade relations of the United States and an international conference at Geneva is attempting to devise methods by which a more uniform system for the interchange of goods between the nations may be worked out, it may appear that so far from it being "imperative" that the United States should develop alternative methods for the production of aluminium, it is in every way desirable that that country should continue to import bauxite and should if possible increase her foreign purchases, rather than attempt to reduce them.

The statement by the Bureau of Standards is no doubt coloured by the aftermath of war conditions. The document from which it is quoted contains a technical description of methods which have been developed for the extraction of aluminium from clay and it is stated that investigations were started in 1941 when shipping losses caused by submarine attacks in the Caribbean Sea were seriously interfering with bauxite supplies. As a war measure, under such conditions, the development which was undertaken was clearly justifiable and wise, but that is not to say that it would now be desirable for the United States to apply, on a large scale, the methods which have been worked out and so reduce her imports of bauxite and take a further step towards a self-contained economy. As the cost of aluminium produced by the most promising of the two methods which have been worked out is twice that of aluminium extracted from imported bauxite, it might be assumed that clay extraction is not likely to be undertaken on a commercial scale, but apart from the fact that experience and large-scale production might well result in a lowering of costs, it is not inappropriate to remember that synthetic rubber is still being produced at a cost considerably higher than that of imported natural material.



These considerations do not in any way detract from the technical interest of the description of the investigations which have been carried out and the two processes which have been developed. It is stated that, in the last three-quarters of a century, at least 60 processes for producing alumina (Al_2O_3) from common clays have been proposed. Most of these were impracticable, either owing to their high cost or the low purity of their product. When alumina is reduced electrolytically to metallic aluminium, any impurities present, mainly silica and ferric oxide, pass into the metal. The two methods of recovering alumina from clay have been worked out by the National Bureau of Standards; one is a hydrochloric-acid process and the other an alkaline process, employing a mixture of sodium hydroxide and sodium chloride. In both cases, the main problem concerned is the effective separation of silica and ferric oxide from the alumina, but in the case of the acid process an additional problem arises in connection with corrosion of the equipment.

The basic reactions used in acid-extraction have been employed by earlier workers, and have been used by the Bureau in the analysis of bauxite and other investigations, but it is claimed that the procedure developed constitutes the first successful attempt to produce uncontaminated alumina by the hydrochloric-acid process. In the spring of 1942, funds were made available for the construction of a pilot plant to test the acid process on a semi-works scale; owing, however, to difficulty in obtaining equipment, the plant was not completed until May, 1943. Difficulties encountered during the earlier work on this method, and caused by the corrosion of metal parts by acid fumes, were eliminated by the use of plastics, glass and refractory materials. The two major problems which had to be dealt with in the preliminary work were the decomposition of clay with hydrochloric acid and the effective separation of aluminium from iron and other soluble constituents of the clay. In connection with the first problem, alumina can be dissolved out of all clays by treatment with hydrochloric acid in closed containers at 300 deg. C., but the high pressures developed rendered this method unsuitable with the equipment available. It was found, however, that after roasting the clay at 700 deg. C. it was possible to dissolve out the alumina with dilute hydrochloric acid at about 100 deg. C. under atmospheric pressure, leaving the silicon in the form of silica (SiO_2) insoluble in the acid.

The problem of separating the aluminium from iron and other acid-soluble constituents of the clay was dealt with by treating the acid solution with hydrochloric-acid gas, the aluminium being precipitated in the form of hydrated aluminium chloride, almost all of the impurities being left in solution. A simplified flow sheet of the acid extraction process, as finally developed, is given in Fig. 1, on this page. The various stages involved are: roasting the clay, digesting the roasted pro-

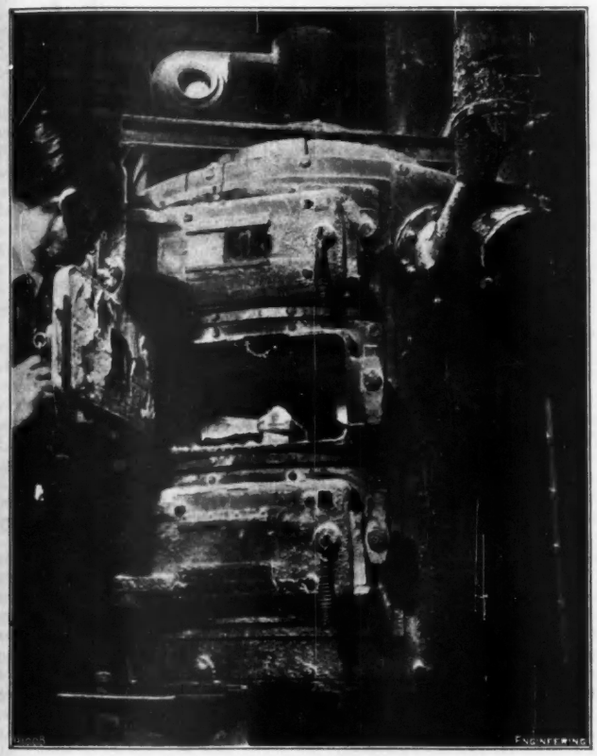


FIG. 2. ROASTING KAOLIN.

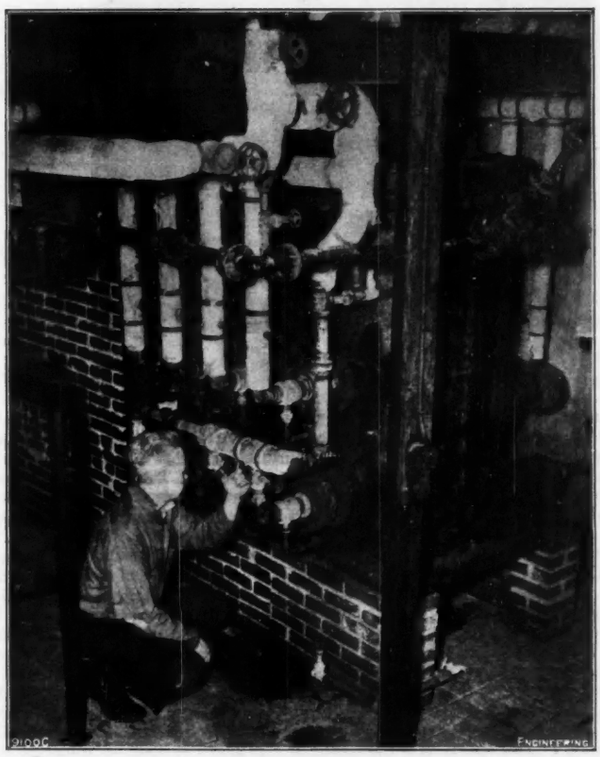
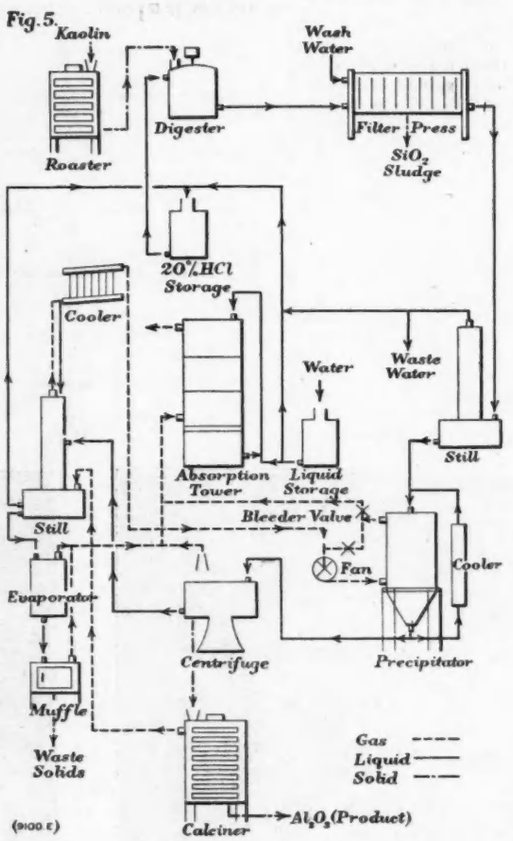


FIG. 3. DIGESTER.

THE EXTRACTION OF ALUMINIUM FROM CLAY.

FIG. 4. FILTER PRESS.



duct in dilute hydrochloric acid, filtering to separate the insoluble siliceous matter from the solution containing the aluminium and soluble impurities such as iron and alkali salts, concentrating the solution, precipitating the aluminium in the form of hydrated chloride from the solution, by adding hydrochloric-acid gas, removing the crystals of hydrated aluminium chloride, washing the crystals to remove adhering impurities, calcining the hydrated chloride to obtain alumina, and recovering hydrochloric acid from the waste products at the end of the process.

It is stated that the process is suitable for the treatment of nearly all clays, but, as it was easily accessible, the work on the pilot plant was carried out with kaolin ($Al_2Si_2O_7.OH_2O$). The raw material is roasted at about 700 deg. C. in a triple-hearth furnace. This operation is illustrated in Fig. 2, on page 265. The powdered clay is stirred by rabble arms as it passes downward through the three hearths. The material then passes to a digester, shown in Fig. 3, on page 265, in which it is stirred in hot dilute hydrochloric acid until the aluminium content is dissolved out as alumina, the silicon remaining as insoluble silica. Digestion is carried out for about one hour at 100 deg. C., after which the slurry is brought to about 60 deg. C. by turning off the steam and circulating cooling water through the heaters. The solution, carrying the insoluble matter in suspension, then passes to the filter press, shown in Fig. 4, on this page, in which the silica sludge is removed. After all the slurry has been pumped into the press, the filter cake is blown dry with compressed air and then washed with water. The acid filtrate and washings then pass into a still in which the solution is evaporated to a relatively small volume, in order to minimise the quantity of hydrochloric-acid gas required for the next stage of the process in which the aluminium is precipitated as hydrated chloride ($AlCl_3.6\,H_2O$). The water distillate is discarded, but the acid distillate is retained for future decomposition of clay in the digester. These stages in the process are indicated in the complete flowsheet which is reproduced in Fig. 5, above.

The concentrated solution is cooled and then enters a precipitator in which it is brought into ultimate contact with hydrochloric-acid gas. The precipitator is illustrated in Fig. 6, on this page. The cooled solution is pumped into the tank *a* and, by means of a glass pump located below the level of the outlet *b*, is then circulated to the top of the unpacked tower *c*, which is 9 ft. high. The solution, passing through the perforated plate *d*, falls through the tower against an ascending stream of hydrochloric-acid gas which enters at *e*, the perforated plate breaking up the descending stream to expose more surface to the gas. As hydrochloric-acid gas is absorbed more readily at low temperatures than at high, a cooler is interposed between the circulating pump and the top of the tower; this is indicated in Fig. 5. Any unabsorbed gas passes out of the tower at *f* and is re-circulated. From the precipitator, the aluminium chloride, suspended in a solution saturated with hydrochloric acid, passes to a rubber-coated centrifuge with a perforated basket. The solution is forced through an asbestos cloth on which the chloride crystals are trapped; any impurities adhering to them are removed by washing with an hydrochloric-acid spray.

(To be continued.)

"VICKERS NEWS."—We have received the first issue of a new series of the monthly house magazine of the Vickers group of companies. It is entitled *Vickers News*, and is an attractive little publication dealing with news of general production activities and local and social events. As is usual, the circulation will be largely confined to the company's employees and overseas agents. It may be remembered that the magazine ceased publication in February, 1942, owing to war conditions. The new periodical is similar in scope to that previously issued, but the page size is somewhat smaller.

LITERATURE.

Radiant Heating. By T. NAPIER ADLAM. The Industrial Press, 148, Lafayette-street, New York 13, U.S.A.; and Machinery Publishing Company, Limited, National House, West-street, Brighton 1, England. [Price 35*s.* including postage.]

"FOR many years the art of heating a building was considered as being so simple that it did not require scientific study and probably for that reason technical developments in heating lagged for many years as compared with other arts." Thus runs a passage in Chapter I of this latest addition to the ever-growing volume of literature on the subject of heating, which itself provides abundant evidence that any leeway is being rapidly made up. It is gratifying (even if the interest has become somewhat academic during the past year or so) to note that modern methods of heating originated in England: a rudimentary form of central heating by hot-water pipes was installed in the Bank of England in 1790, and "panel heating" in its modern form, was introduced by Professor A. H. Barker in 1908. This latter method was really a rediscovery, as floor heating was practised by the Romans. Excellent examples of Roman hypocausts exist at various places in England, including Bath, near which city, the author states, he spent several years assisting Professor Barker in his researches. The Roman method of heating has been adopted in principle for Liverpool Cathedral, and a description of this installation is given.

The term "radiant heating," however, in this work mainly connotes heating by means of small hot-water pipes embedded in the structure of the building, and the greater part of the book is devoted to a consideration of this system. It summarises the author's 30 years of experience in Europe and the United States, and is essentially of a practical character, being written in a simple and almost popular style. This, however, does not in any way detract from the value of the book. The 300 or so

well-chosen illustrations include clear lay-out diagrams, showing, *inter alia*, some features usual in American heating practice, but rarely met with here, such as a cold-water supply to the boiler directly from the mains, through a relief valve and pressure-reducing valve, and expansion accommodated in an air-vessel, under pressure, contiguous to the boiler. There are useful chapters on air venting, flow adjusting and controls. Some account is given of radiation theory, with a clear explanation of the method of determining the all-important "mean radiant temperature" (M.R.T.). The section on design is of particular interest, as it introduces a step-by-step procedure, and gives all the physical constants and other data required for carrying out a complete design. The methods are applicable not only to panels of embedded pipes, but also to metal panels and electrical heating systems of various kinds.

In the examples of floor heating given, the surface temperature is taken as 85 or even 90 deg. F. Such temperatures are apparently acceptable in America, but in this country, where floor panels are not used extensively now, 70 or 72 deg. F. appears to be the comfortable limit. An explanation of this difference would have been interesting. There is, however, a detailed discussion of the factors involved in comfort, introducing yet another term in the somewhat involved nomenclature of this subject—the "operative temperature." The author recommends, for ordinary conditions in schools, offices and residences, in America, an M.R.T. of 72 deg. F., and air temperature 68 deg. F.; and, for England, M.R.T. 65¼ deg. F. and air temperature 62 to 63 deg. F. The figures for America satisfy the "comfort equation" used there, and the author remarks that some authorities in England recommend, for radiant-heating systems, lower air temperatures than those quoted. Charts are given enabling calculations to be made under both American and European conditions.

The sub-title of the book is "Radiant Cooling and Snow-Melting," both of which subjects hitherto have had more application in America than in this country. The utility of the former depends largely on the relative humidity, and the author states that moisture does not deposit on a plaster surface until its temperature is from 3 to 5 deg. F. below the dew point of the air. Thus with a surface temperature of 58 deg. F., it would be possible to have a relative humidity of up to 45 per cent. These figures are applicable, no doubt, under American conditions, but should be used with care in England, where relative humidities considerably higher than 45 per cent. are frequent. A minimum floor temperature of 70 deg. F. is recommended and, as producing very comfortable conditions with a relative humidity of 40 per cent., an M.R.T. of 74 deg. F., and an air temperature of 80 deg. F. These figures, of course, apply to America, where summer temperatures of 95 or 100 deg. F. are experienced.

The chapter on snow melting gives much information on the use of hot-water pipes to prevent the accumulation of snow and ice on paths and driveways, steps of public buildings, and aerodrome runways. Engineers concerned with the design and installation of panel heating and allied systems will find Mr. Adlam's book a valuable source of information.

THE LATE MR. HENRY SAVAGE.—Many persons in the electrical industry will learn with regret of the death of Mr. Henry Savage, which occurred at his home in Folkestone on September 7. Mr. Savage, who was 72 years of age, was formerly works manager of Messrs. W. T. Henley's Telegraph Works Company, Limited. He received his education at the Royal Arsenal School and joined the firm's North Woolwich works in June, 1890, as a junior test-room assistant. He continued his technical education by taking courses at East London (now Queen Mary) College, and at University College, London. In 1919, he became joint works manager at the North Woolwich works with the late Mr. R. J. Hatton, and a year later was appointed works manager when Mr. Hatton retired from the managership. Mr. Savage retired, in his turn, on June 30, 1930, after 40 years' service. He was elected an associate member of the Institution of Electrical Engineers in 1900 and became a member in 1911. He was also an associate member of the American Institute of Electrical Engineers and a Fellow of the Institution of the Rubber Industry.

ENGINEERING AND MARINE EXHIBITION AT OLYMPIA.

(*Concluded from page* 248.)

A SECTION of the exhibition, which closed on Saturday, September 13, was devoted to a display of electric-welding equipment. This was organised by the Welding Division of the British Electrical and Allied Manufacturers' Association, 36, Kingsway, London, W.C.2, and included the majority of British manufacturers of arc-welding plant and electrodes, and resistance welding machines. The Welding Division also had a separate information stand. Although it has not been possible for us to group our descriptions of this welding apparatus in our account of the exhibition, it may be mentioned that a uniform design of fascia board and colour scheme was adopted on all the stands, so that they formed a specialised display. Among the exhibits, of which mention may be made, were those of Murex Welding Processes, Limited, Waltham Cross, Hertfordshire, which covered a wide range of arc-welding plant, accessories and electrodes. Included in them was a mobile 400-ampere Diesel-engine driven set of a type which has been supplied in large numbers for use in oilfields. Care has been taken therefore to ensure that it will operate satisfactorily in ambient temperatures up to 125 deg. F. and in high altitudes and humidities, as well as in sand-laden atmospheres. It has also been designed to withstand rough handling and bad roads, and to give accessibility to all parts. The set consists of a four-cylinder Dorman DS engine, which is directly coupled to a generator with a drooping characteristic and designed to give a stable arc. Both engine and generator are provided with sand filters. To allow for transport over bad roads, the overall height of the set from the ground has been kept down to 5 ft., while the height of the engine and generator shaft centres is only 1 ft. 11 in. The track is 4 ft. 11 in., to ensure adequate stability over uneven ground. The wings, which are fitted over the 6 in. by 16 in. tyres, are intended primarily to give protection from the sun. The fuel tank, which is lead coated, has a capacity of 16 gallons, which is said to be more than sufficient for one day's running without refuelling. To prevent pilferage of the components on site, the set is fitted with four steel roller shutters, which can be raised or lowered easily and secured by a simple padlock.

This exhibit also includes the firm's 300-ampere motor-generator set. This is mounted on a trolley and is equipped with the Murex remote-control regulator, full details of which were given in ENGINEERING, vol. 163, page 425 (1947), in our account of the British Industries Fair at Birmingham. It may be recalled, however, that this apparatus is designed to save the production time which is frequently lost when the operator has to adjust the welding current to meet the varying requirements of the work. All that is necessary with this controller is to short-circuit the electrode holder to the work. If this short is maintained for about 1½ seconds, the relays, motor and mechanism, which are housed in a separate steel box, come into action and the control automatically turns towards minimum. A reduction in the current thus occurs, so long as the short-circuit is maintained. To increase the current the operator makes a very brief short-circuit followed by a long one. After the lapse of about 1½ seconds, the control then automatically turns towards maximum and the current is raised, again so long as the short-circuit is maintained. In both cases the control stops and remains at the new setting when the short-circuit is removed.

Most of the visitors to the stand of the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, were interested in the model of a section of an all-welded destroyer, which illustrated the importance of welding equipment in the modern shipyard. The display on this stand also included models of the firm's direct-current and alternating-current stud-welding gear. This consists essentially of a gun tool in which the stud is located by a special chuck. The gun is located accurately and firmly by three adjustable legs, so that the stud can be welded vertically to the work. Operation is entirely automatic, the welder having only to press a trigger on the gun tool to complete the welding process, which takes about 1 second. The studs are made of mild steel and embody a small accurately-dimensioned tip at the welding end. The chuck, in which the stud is held, is spring loaded, the spring being released by an electrical device in the gun tool. When the switch trigger on the gun tool is pressed, a mechanical timing device, which is mounted on the current-regulator tank, comes into operation. This device is operated by a relay, which is supplied with direct-current from an auxiliary transformer and rectifier and, in turn, starts a small timing motor. This motor drives, through reduction gearing, a shaft, on which there are a number of cams, and these cams open and close auxiliary switches in sequence. Once the motor has been started it continues to rotate until the weld is completed, thus taking the control out of the hands of the operator.

The welder is connected to a standard 50-cycle alternating-current supply, the pressure of which is stepped down to a suitable value by a transformer. The secondary voltage is then rectified by an Ignitron, which, together with the auxiliary equipment for operating it, is oil-immersed in a steel tank. The operator can adjust the current to the correct value for the various sizes of stud by a switch on the regulator. The timing mechanism is also controlled by a switch, so that the time is suitable for the diameter of stud being used. These switches are operated from outside the tank. The sequence of operations, therefore, is that after the current and time have been set, the gun tool, with the stud held in the chuck, is located in the exact position on the parent plate. When the trigger is operated, direct-current flows from the plate through the stud and the pip at the base of the latter is fused. After a pre-determined-time, the current in the control circuit on the gun tool is switched off by the timing mechanism, so that the stud is forced by spring pressure into the pool of molten metal on the plate and welded to it. The main current is then switched off by the timing mechanism.

Among the numerous welding machines, which were exhibited on the stand of Messrs. Sciaky Electric Welding Machines, Limited, Slough, mention may be made of the air-operated circumferential seam welder illustrated in Fig. 69, page 268. This machine has a nominal loading of 50 kVA and gives welding speeds of from 2 ft. to 9 ft. per minute on steel, brass and light alloys. The direction of the wheel drive is reversible, driving being effected from a three-phase motor through infinitely-variable gearing. The welding pressure head is supplied with compressed air through a three-way electrically-operated air valve; and the current is controlled by a modulator, which consists of a single-phase induction regulator, the stator of which is connected to the supply mains, while the rotor is in series with the welding transformer. The varying rotor voltage is then superimposed on the mains voltage applied to the transformer, so that a series of voltage peaks result. Welding is arranged to take place during the period of each peak, although pre-heating takes place to a certain extent during the intervening periods. The frequency at which the peaks occur can be varied by altering the modulator speeds. Alternatively, two Ignitrons, which are connected in reverse parallel, can be used to control the duration and value of the welding current. With this arrangement, the "on" and "off" times are adjustable in half-cycle increments from 0·5 cycle to 40 cycles. Phase control is also provided on this machine, so that the welding heat can be adjusted smoothly without changing the taps on the welding transformer. The timing of the "on" and "off" periods is effected by synchronous motor, which drives an endless chain the length of which can be varied. This chain is made up of master links, which carry conducting and non-conducting buttons. These buttons, each of which represents one half cycle of the fifty-cycle power system, can be arranged in any order by the operator. In this way, it is claimed, the timing pattern can be altered without the use of tools. The Ignitrons themselves are steel-jacketed and water-cooled.

Another machine on this stand, of which mention

EXHIBITS AT THE ENGINEERING AND MARINE EXHIBITION.

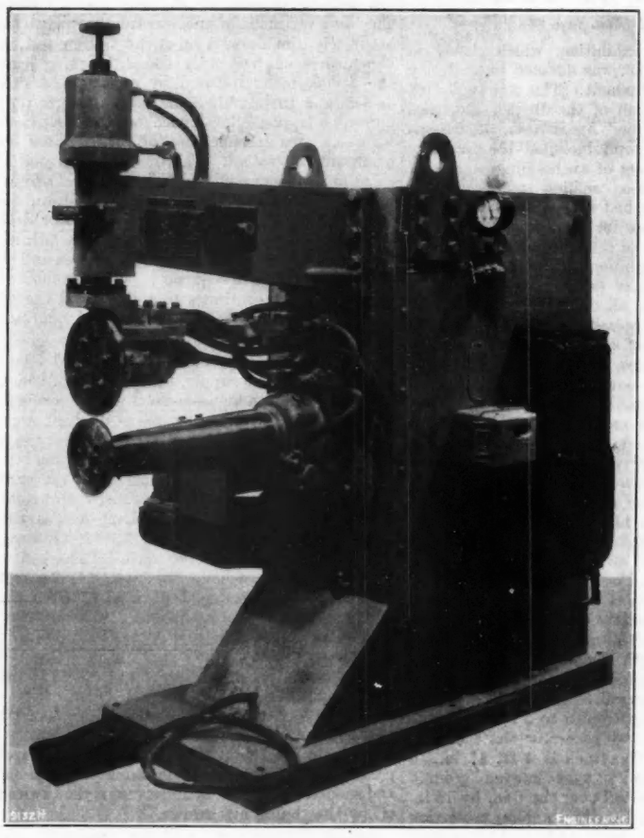


FIG. 69. AIR-OPERATED CIRCUMFERENTIAL SEAM WELDER; MESSRS. SCIAKY ELECTRIC WELDING MACHINES, LIMITED.

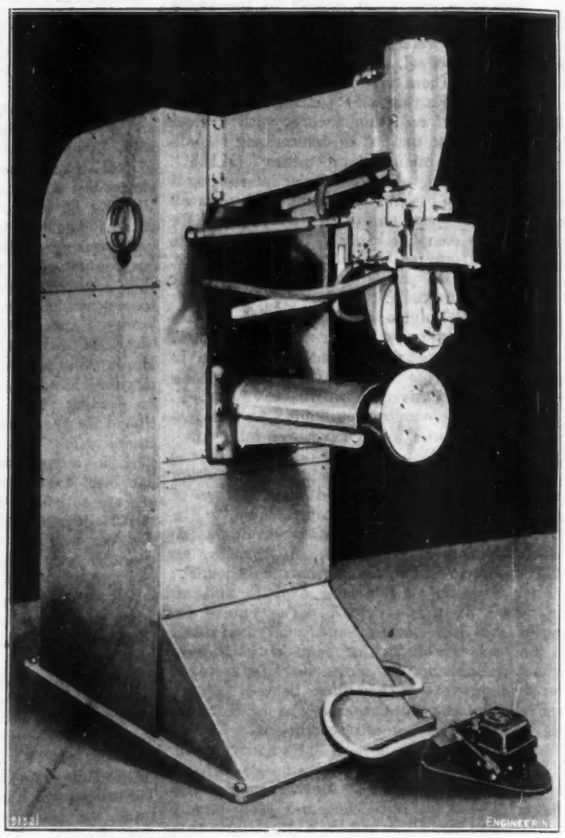


FIG. 70. AIR-OPERATED UNIVERSAL SEAM WELDER; MESSRS. SIEMENS-SCHUCKERT (GREAT BRITAIN), LIMITED.

may be made, was an automatic indexing projection welder. This machine is designed to produce up to 45 projection-welded components per hour. The parts to be welded are fed by the operator into ten welding jigs, which are mounted on a rotary indexing table arranged so that from 15 to 45 welds per minute can be obtained. The intermittent revolution of the indexing table is effected by a Geneva movement, which is driven by an electric motor through an infinitely-variable gear. At the conclusion of the welding cycle, the components are automatically ejected from the machine. Control of the primary current is effected by an Ignitron contact panel, while the timing sequences can be adjusted by resistance-capacitance circuits. The machine is completely interlocked, so that if operation fails, or is incomplete, when the table is ready for indexing to the next welding position, the motor is switched off and a brake is applied which brings the machine to a standstill. If the reason for the stoppage is merely that an operation, such as the return of the top electrodes, has slowed down, immediately step has been regained with the rest of the mechanism, the motor is automatically restarted. The indexing and welding sequences can therefore be recommenced without the machine having to be re-set.

Messrs. Siemens-Schuckert (Great Britain), Limited, Great West-road, Brentford, Middlesex, were showing welding machines of various types, as well as a high-temperature muffle furnace and industrial X-ray equipment. The welding machines included the air-operated universal seam welder for the longitudinal and circumferential welding of mild steel up to No. 18 gauge; this machine is illustrated in Fig. 70. It includes a modulator which provides the modulated current necessary for welding airtight seams. As is customary, this modulation is achieved by superimposing a varying rotor voltage on the main voltage supplied to the transformer, the result being a series of voltage peaks during which welding takes place. High-conductivity hard-wearing copper alloy is used for both the upper and lower electrodes, each of which is 9 in. in diameter. Both the electrodes, as well as the lower arm and the main transformer, are water-cooled. The arms are 24 in. long and the machine is suitable for welding speeds from 2 ft. to 12 ft. per minute. A much smaller machine shown by the same firm was a 4-kVA spot welder, which is pedal-operated and is suitable for dealing with sheet up to No. 22 s.w.g. in thickness. A special point about this machine is that the upper electrode moves parallel to its length like a plunger.

Messrs. Petbow, Limited, Station Estate, Balmoral-road, Watford, Hertfordshire, were exhibiting an arc-welder, which has been designed for conditions where light weight and mobility are of prime importance. The total weight is only 9 cwt. The engine is of the Ford industrial type and is capable of developing 19 brake horse-power at a speed of 2,100 r.p.m. It is fitted with a Solex down-draught carburettor, the suction governor on which operates in event of a failure of the centrifugal governor, so that the engine speed is limited to 2,400 r.p.m. A pressure-feed system of lubrication is provided, with an oil cooler between the pump and bearings and an Auto-Klean filter. The centrifugal governor is mounted on the cylinder head. It is driven by a shaft, mounted on ball bearings, at one end of which is a 16-in. fan and at the other a centrifugal water-circulating pump. The shaft is driven from the crankshaft pulley by a V-belt. Ignition is by magneto. The generator, which is coupled to the engine by a flanged housing, is of the single-operator drooping-characteristic type, with a maximum output of 250 amperes at 25 volts. Its output is controlled by a selector switch and fine adjustment regulator, which is built into a sheet-steel cubicle. Cooling is effected by a centrifugal fan on the armature shaft, the air being drawn in through openings which are protected by louvres. The set is covered by a steel canopy, which is hinged to give easy access to the engine controls and tank filler. It can be mounted on alternative types of carriage which are suitable for man haulage, for low-speed motor towing, or complying with the towing conditions in the British Road Traffic Acts.

Among the exhibits on the stand of the Lincoln Electric Company, Limited, Welwyn Garden City, Hertfordshire, was the "Shield-Arc Sae" welder. This consists of a squirrel-cage motor, which is designed for across-the-line starting and for taking heavy loads. The motor is provided with a control device giving protection against overloads, no-voltage and under-voltage. This device consists of two current transformers and two snap-action thermostats, which are mounted directly on the motor laminations, so that they operate both by conduction and the current passing through them. If the temperature of the welder exceeds a safe value, the thermostat will operate, but it will also come into action if the motor is cold, so that damage will not be caused by excessive current, which might flow for short periods. Similarly, operation occurs if the fuse on one phase blows, if the rotor is locked, or if the welder is used for long periods at sustained overloads. The motor is directly connected to the generator, a separate exciter being mounted on the same shaft. The generator is of the variable-voltage type, with a completely laminated magnetic circuit, and is equipped with interpoles so that no external reactance or stabiliser is required. The open-circuit voltage can be adjusted by a shunt field rheostat, while the current can be varied independently in a continuous sequence of fine steps by controllable series-field current. It is claimed

EXHIBITS AT THE ENGINEERING AND MARINE EXHIBITION.

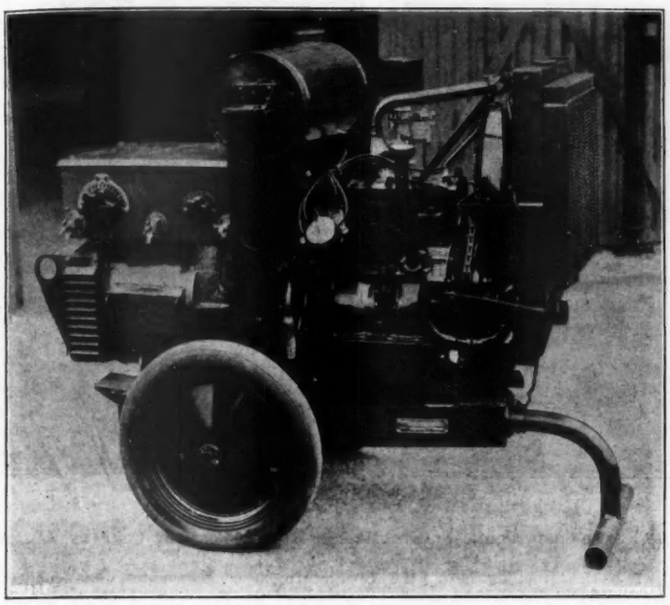


FIG. 71. PETROL-ENGINED WELDING SET; THE QUASI-ARC COMPANY, LIMITED.

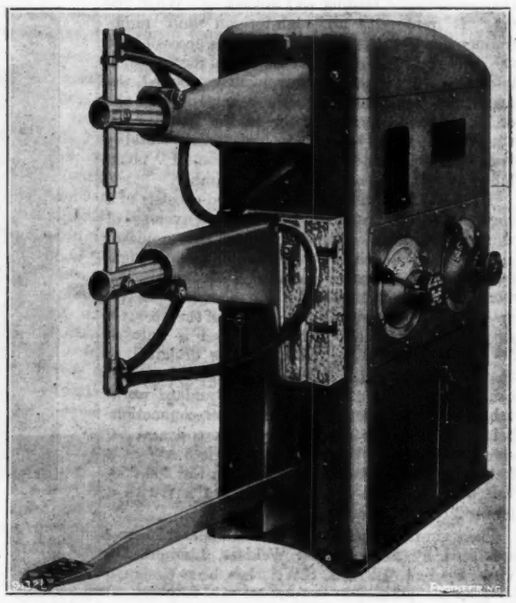


FIG. 72. HIGH-PRESSURE SPOT WELDER; MESSRS. A.1. ELECTRIC WELDING MACHINES, LIMITED.

that, by this means, the operator can select the type of arc or arc intensity best suited to the work. All the controls are enclosed in a steel cabinet, the alternating-current circuits, direct-current controls and direct-current output terminals being housed in separate compartments.

The petrol-engine-driven portable lightweight welding set illustrated in Fig. 71 was exhibited by the Quasi-Arc Company, Limited, Bilston, Staffordshire. It has been designed to meet the increasing demand for a machine which can be quickly dismantled and assembled and thus easily carried to and from the welding site. For this purpose, it is divisible into two sections, which can be carried by four men. When assembled, it is carefully balanced and, being provided with pneumatic-tyred wheels and a drawbar, can be manipulated conveniently by one person. The overall dimensions are 58 in. by 22½ in. by 45 in. high, and the total weight when assembled is 7¼ cwt. The engine is of the four-cylinder Austin type, with a normal rating of 20 brake horse-power at 2,200 r.p.m. It is arranged for hand starting and is equipped with a Solex combined air-velocity type governor and carburettor, magneto, oil and air filters, and water pump. It is directly coupled to a lightweight self-stabilising direct-current generator, which operates with a drooping characteristic. The output of this generator is controlled by an eight-point selector switch, which is mounted in a sheet-steel box on the generator frame, and by a shunt-field rheostat, by which the welding current can be finely adjusted. It is claimed that these two current controls give smooth stepless welding-current regulation throughout the range from 20 amperes to 250 amperes, and enable all types of both ferrous and non-ferrous electrodes from 16 s.w.g. to 4 s.w.g. to be utilised. The set is enclosed in an aluminium housing which can be provided with locking mechanism.

A second portable set exhibited on this stand comprised a Ruston two-cylinder Diesel engine, which is directly-coupled to a generator with a welding-current range of from 20 amperes to 300 amperes. Control is effected by the firm's latest form of dual control which gives sensitive control of both the striking voltage and welding current, thus allowing the operator to select the welding characteristic best suited to the work in hand. The engine and generator are mounted on a common framework and are enclosed in a weather-proof housing which is fitted with louvred sliding doors so that easy access is possible to the controls. The rating is liberal, so that the set should be particularly suitable for operation under arduous overseas conditions.

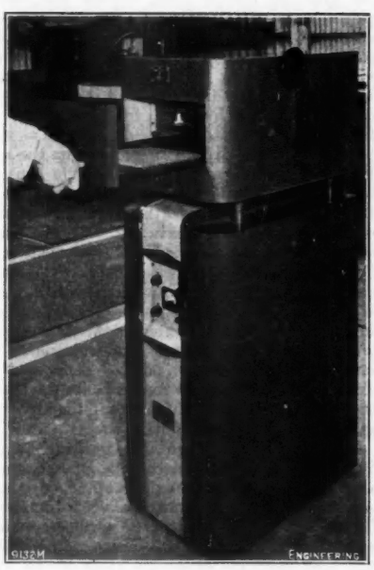


FIG. 73. DIELECTRIC-HEATING PLANT; MESSRS. A. C. WICKMAN, LIMITED.

A.1. Electric Welding Machines, Limited, 64, Victoria-street, London, S.W.1, were exhibiting a 100-kVA flash butt welder, which has been designed for welding mitres and reverse bars over the full range of window-frame sections. The machine is air operated and control is fully automatic. Sections up to 4 sq. in. of mild steel can be dealt with on a second flash butt welder shown by this firm, the electrical capacity of which is 250 kVA. On this machine, the clamps and the automatic-control mechanism which operates the flashing and upsetting cycle, are arranged for operation by air pressure, while preheating, which is employed on solid sections, is effected manually. Special mention may be made also of the firm's latest pedal-operated spot welder, which is illustrated in Fig. 72. This is designed to cover a wide range of work in the assembly of steel sections by spot welding. The arms are 24 in. long and will accommodate work up to 48 in. wide by welding from each side. The water-cooled copper electrodes are interchangeable and are arranged to take taper fixing electrode tips. The welding pressure is transmitted from the pedal lever to the electrodes through the firm's oil intensifier unit. This is located on the backshaft and is adjustable so that the welding pressure can be altered to suit different thicknesses of plate. The welding time is controlled by an electro-pneumatic timer and magnetic contactor, over a range of from $\frac{1}{10}$-second to 4 seconds. To prevent underforging of the weld by the premature release of the pedal, an interlock is fitted which makes it impossible for the electrodes to open until the current has been applied for the correct time and the consolidation of the weld has been completed. The action of this interlock is shown on an illuminated indicator on the front of the machine.

Welding current is supplied through a 25/50 kVA transformer, which is mounted in the pedestal. This transformer is liberally rated and is equipped with two tapping switches, by means of which twelve secondary voltages can be obtained. The secondary windings are water cooled, a water supply of about 60 gallons per hour being necessary for this purpose and for cooling the electrodes. This is obtained through a connection on the machine pedestal, the amount of water flowing being indicated by a tundish.

Messrs. A. C. Wickman, Limited, Banner-lane, Coventry, exhibited several types of equipment for plastic welding, and dielectric and induction heating. These included a 1-kW induction heater for brazing Wimet-tungsten carbide tips to turning-tool shanks. Typical of the dielectric heaters is the model illustrated in Fig. 73, which comprises a 1-kW thermionic valve oscillator with a built-in high-tension direct-current power unit. The oscillator consists of a silica-envelope valve to the anode of which a wide range of work can be matched by altering the taps in the tank circuit. This generator is capable of delivering 1 kW at a frequency of about 30 mega-cycles per second under which conditions the load on the 200/250-volt 50-cycle single-phase mains is about 2 kW at a power factor of 0·9. The heating

chamber is provided with 12-in. by 12-in. electrode plates, which can be adjusted up to 4 in. by a hand-wheel on the side; it is fitted with a removable tray to facilitate loading and unloading. When the tray is removed, all high-tension and radio-frequency current is cut off from parts accessible to the operator. The meters and controls for the oscillator and work-table are conveniently grouped, the main fuses being housed on the rear panel and the oscillator anode-current meter on the front panel, with the trip re-set button, the high-tension standby switch, and indicator lights. The "on-off" push-button is mounted on the heating chamber.

The 5-kW induction heater exhibited consists of a thermionic-valve oscillator, the silica envelope of which is air-cooled. The output from this oscillator is fed into the primary of a double-wound high-frequency transformer in the work-table. The work coils are connected to the secondary of this transformer, thus ensuring the safety of the operator as the high-frequency voltage applied is only at 50 to 100 volts. The work-table is designed so that all necessary jigs, fixtures and quenching trays can be incorporated. In fact, the standard work-table includes a quenching bath, water connections being provided for cooling the work coil and for spray quenching. When the output is 5 kW at a frequency of 1 megacycle, the load on the 200/250-volt 50-cycle single-phase mains is 9·4 kW with a power factor of about 0·9.

The twin-head seam-welding machine, which was exhibited by New Process Welders, Limited, 76, Victoria-street, London, S.W.1, has been designed to give the maximum output on the longitudinal seams of radiator units. It is adaptable for two-, three- and four-flute units in which the distance between the weld paths is 3 in., 4½ in. and 6 in., respectively. The machine consists of a fabricated steel frame in which the transformers are housed. This is surmounted by two square steel bars on which two cast-iron saddles are carried. These saddles can be moved along the bars by a lead screw and hand wheel and support bronze platens, each of which carries a lower disc-electrode housing assembly and a bracket bearing a cylinder 5½ in. in diameter. The piston of this cylinder is attached to a second disc-electrode assembly, so that the necessary welding pressure can be applied. This pressure is adjustable by reducing valves. The top electrodes are driven by a 2-h.p. motor through sprockets on a main shaft running along the back of the machine. Further sprocket drives run from this shaft to knurled steel driving wheels, which press against the periphery of the disc. The optimum welding speed is between 6 ft. 6 in. and 7 ft. per minute, but adjustments can easily be effected by changing the sizes of the sprockets or the diameters of the knurled driving wheels. The primaries of the transformers, each of which is provided with five tappings, are connected in parallel, while the secondaries are independently connected to a pair of electrodes on each side of the welder. The current is controlled by a double-pole contactor, the necessary interruptions being effected by a rotary modulator which, like the contactor and the relays, is housed in a separate cubicle. The machine is designed to run continuously, the only control being provided by a pedal which interrupts the current to prevent burning when a change-over is made from one radiator to the next.

Unfortunately, lack of space prevents us from giving detailed descriptions of the exhibits in several of the sections of the exhibition, one of which was devoted to foundry appliances and materials. A brief review of some of the exhibits, however, is given below. A typical British product was the sand-conditioning plant illustrated in Figs. 74 and 75, on this page, which is manufactured by Messrs. Heaton Foundry Company, Limited, Heaton Junction, Newcastle-on-Tyne. Since the actual machine was too large to be accommodated, a working model of the latest design was shown on the stand of Messrs. Thos. W. Ward, Limited, Albion Works, Sheffield, this firm being the sole distributors of the Heaton Foundry Company's foundry plant, which has the generic trade name of "Polford." The machine illustrated has a sand-conditioning capacity of up to five tons an hour and is designed to deal with the preparation and reconditioning of all kinds of

THE ENGINEERING AND MARINE EXHIBITION.

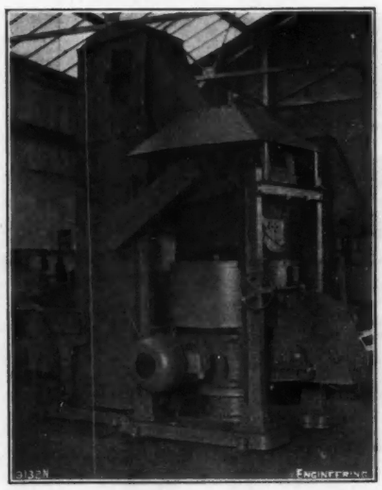


FIG. 74.

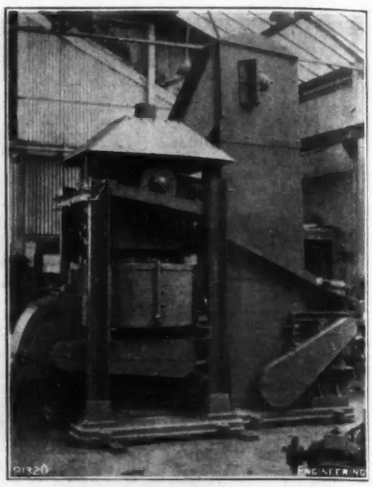


FIG. 75.

FIGS. 74 AND 75. SAND-CONDITIONING PLANT; MESSRS. HEATON FOUNDRY COMPANY, LIMITED.

foundry sand. It will be clear from Fig. 74 that the drive is by a flange-mounted totally-enclosed motor; transmission is through worm gearing running in an oil bath. The sand to be treated is fed, either by hand or mechanically, into a hopper at the rear of the machine, and in going through the machine passes a magnetic tramp-iron remover, this being chiefly of service when dealing with old sand; a roller crusher for breaking down sand lumps; a vibratory screen; a mixer miller; and dust extractor. Fitted to the discharge door is an aerator, the drive for which is by V-belt from the motor. The function of the aerator is to sling the sand as well as to aerate it; the drive casing is seen on the left of Fig. 75. The vertical casing on the right houses the bucket elevator, which lifts the sand from the feed inlet and discharges on to the vibratory screen, the casing of which is visible in Fig. 74. The plant is self-contained and the electrical equipment is controlled from a central switchboard. Guards and electrical interlocks are provided and ball-bearings are fitted to all the rotating parts. Other apparatus in the Polford range exhibited on the stand included a central-axis tilting furnace, a mould drier, a core-sand mixer and a mixer miller. There were also examples illustrating raw materials for the foundry trade, such as a variety of pig irons, foundry cokes, ganister, fluorspar, limestone, etc.

Messrs. J. W. Jackman and Company, Limited, Vulcan Works, Blackfriars-road, Manchester, 3, also had an interesting exhibit of foundry plant. Among the numerous machines shown was the Osborn pneumatic jolt-squeeze stripper, which is a moulding machine of a new design. This machine will take moulding boxes up to 28 in. by 18 in. with a pattern draw up to 6 in.; the jolt cylinder is 5 in. in diameter and the squeeze cylinder is 12 in. in diameter, both cylinders being separately arranged for economy and ease of replacement. It was noticeable that great care had been taken to ensure that all parts of the draw mechanism should function with uniform accuracy and that the movements of the four lifting pins are truly synchronised. The draw is controlled by a combination hand and knee valve, so that the operator can lower the draw frame by knee action while both hands are engaged in lifting off the mould. Other exhibits on this stand included a sand mill and mixer, a motor-driven gyratory sand sifter arranged to discharge the tailings during sifting, an Osborn pneumatic roll-over jolter, an Osborn pneumatic core blower, and a variety of sand-blast and shot-blast machines.

Messrs. Coleman Foundry Equipment Company, Limited, Stotfold, Bedfordshire, showed a variety of machines for foundry use, including abrasive cutting-off machines, while the exhibit of Messrs. Tilghman's Patent Sand Blast Company, Limited, Broadheath, near Manchester, was confined to examples of the firm's shot-blast equipment and auxiliaries. The Constructional Engineering Company, Limited, Charles Henry-street, Birmingham 12, showed various types of moulding machine, together with examples illustrating cupola construction, core-ovens, ladles and a horizontal centrifugal casting machine with electronic control giving infinitely-variable speeds. Furnaces of a wide range of types were shown by Messrs. Monometer Manufacturing Company, Limited, Clifton-drive, Westcliff-on-Sea, Essex, for different metals, and also a white-metal pressure-casting plant for lining bearings. Messrs. Stone-Wallwork, Limited, 157, Victoria-street, London, S.W.1, showed, in addition to moulding machines, a complete semi-automatic moulding unit serving the moulding boxes of two straight-draw machines. Messrs. British Moulding Machine Company, Limited, Faversham, Kent, exhibited moulding machines and core-making machines with examples of the castings made by their use.

One of the more unusual exhibits, though small, may be mentioned. This was a new instrument known as the "Reciproscope," shown on the stand of Messrs. Toplis, Simpson and Company, Limited, 130, Vaughan-road, Harrow. The instrument has been designed to increase visibility in fog, mainly, of course, at sea. It does not increase the range of vision by magnification, as binoculars do, though it is employed in a similar way. When used in a fog through which an object may be dimly visible but not identifiable, the object can be picked up with certainty at a greater distance than is possible with unaided vision. The instrument consists of a rectangular case, having a carrying strap and measuring 4¾ in. by 3½ in. by 2½ in. One of the larger faces carries a pair of eyepieces resembling those of binoculars but without lenses, while the opposite face has a slot through which the object to be viewed is seen, the rays of light passing this aperture being reflected to the eyepieces by mirrors, one of which can be oscillated. When an object is faintly visible and is viewed through the instrument, it can be more clearly defined by oscillating the mirror. We understand that the instrument has been tested at sea and found satisfactory. In the apparatus exhibited the fog was simulated by a translucent liquid and the results were checked by means of a scale along which an object immersed in the liquid was moved.

Only a brief outline can be given of the activities illustrated in the displays of the several research organisations at the exhibition. The National Physical Laboratory, Teddington, Middlesex, showed some examples of research work in the engineering, metallurgy, metrology and ship divi-

sions of the laboratory. Under the first heading comes the unification of screw threads; the efficient lubrication of oscillating bearings, such as those of gudgeon pins; the effect of high temperatures on engineering materials; electrical-resistance strain gauges; and stress concentration in the fatigue of metals. Under the second heading were illustrated stress-corrosion cracking in alloy steels for gas cylinders and the quantitative measurement of hydrogen in weld metal. The ship division showed a model tunnel for investigating the cavitation phenomena associated with ships' propellers, while the metrology division demonstrated the measurement of air volumes and pressures, the measurement of the teeth of gear wheels and methods of testing surface finish. The Fuel Research Station, Blackwall-lane, London, S.E.10, showed the application of smoke eliminators, developed during the war for reducing smoke from coal-burning ships, to Scotch marine boilers and Lancashire boilers. There was also an atmospheric-pollution exhibit and a "boiler availability" exhibit. The Parsons and Marine Engineering Turbine Research and Development Association, Pametrada Research Station, Wallsend-on-Tyne, showed, among other things, a displacement indicator for use with overspeed tests and similar work; a working model of a double-reduction gear with hydraulic reversing device, and a wave analyser for isolating and measuring the different components of a complex vibration having a wide range of frequencies.

The British Shipbuilding Research Association, 5, Chesterfield-gardens, Curzon-street, London, W.1, showed a pressure-indicating system for measuring fuel-injection pressures in marine Diesel engines; a model illustrating the transverse distortion of ship's framing due to heeling; a torsional fatigue testing machine and the testing of propeller shafts; an actual ship's propeller vibrated so that the nodal patterns can be determined; a fluorescent comparator for determining the oil content of feed water; a vibration-measuring instrument for use on ships; and a number of photographs illustrating other aspects of the research work. The Motor Industry Research Association, Great West-road, Brentford, Middlesex, showed a capacity-type electrical torquemeter suitable for measuring both steady torques and torsional vibrations. The Production Engineering Research Association of Great Britain, Staveley Lodge, Melton Mowbray, had exhibits illustrating aspects of research into drilling, turning and other machining operations. The British Internal Combustion Engine Research Association, 111-112, Buckingham-avenue, Slough, displayed photographs illustrating examples of the engines and apparatus used in investigating the factors related to the performance and durability of this type of prime mover. The British Iron and Steel Research Association, 11, Park-lane, London, W.1, showed a model blast-furnace to illustrate how investigations are carried out on the distribution of raw materials within the blast-furnace; a meter for measuring the tension in wire while it is being drawn at high speed; and a transparent model of the side-blown converter used for investigating the flow of steel during melting.

The British Cast Iron Research Association, Alvechurch, Birmingham, showed samples of the different finishes obtained on cast iron with appropriate data regarding their suitability for various purposes; also some new cast irons and data relating to design and manufacture in this material. The British Non-Ferrous Metals Research Association, Euston-street, London, N.W.1, exhibited a jet-test apparatus as used for comparing the resistance to corrosion of various copper-base alloys by aerated sea water, under conditions similar to those obtaining in marine condenser tubes; a high temperature fatigue-testing machine developed by the Association; and examples illustrating researches made for the improvement of the quality of tin and gunmetal castings and of controlling porosity. The British Welding Research Association, 29, Park-crescent, London, W.1, exhibited welded model frames and battened stanchion members as employed in experimental research on the behaviour of rigid frame structures; instruments developed for the measurement of variables in resistance welding machines, the fatigue testing of welded structures by the resonance vibration method; photographs illustrating researches carried out for the Association by Messrs. Babcock and Wilcox, Limited, to study the stress conditions in various parts of a welded vessel subjected to internal pressure; and photographs and diagrams illustrating "weldability" tests used for research purposes.

The stand displaying all the exhibits enumerated above, of which there were 46 altogether, was arranged by the Department of Scientific and Industrial Research, Park House, 24, Rutland-gate, South Kensington, London, S.W.7, though only two of the classes of exhibits were directly attributable to the D.S.I.R., the various associations responsible for the other classes being autonomous organisations. The associations are financed in part by the industry concerned, but also receive substantial financial assistance from the Government, this latter aid enabling research to be controlled and co-ordinated so that duplication and overlapping may be avoided. The Research exhibit was well chosen and informative and it was supplemented by cinematograph films and by reports and other literature which was available in great variety. Two other Government departments also had stands. One, arranged by the Chief of Naval Information, Admiralty, had a well-selected display from the wealth of material available from the Navy; the other, arranged by the War Office, was equally attractive. In the former case, a working engine-room platform of a modern destroyer and, in the latter, a section of a full-size Bailey bridge, provided the practical aspect of the display, but on both stands exhibits calculated to stimulate recruiting were not neglected.

As has been the practice in previous exhibitions, a large number of official visits were arranged to take place on definite days, arrangements having been made for visits by members of 71 professional, scientific, technical and trade institutions, associations, and other organised bodies. In concluding our survey of the exhibition, we should mention that a considerable number of well-known firms have not been alluded to, an omission which is due mainly to pressure on our space. The standard of the exhibits as a whole, including those not specifically referred to, was of a high order and does credit to the engineering industry, especially when the present difficult conditions are borne in mind.

ENGINEERING AND MARINE EXHIBITION AT OLYMPIA: ERRATUM.—We regret that the photographs of compressors exhibited by Messrs. Peter Brotherhood, Limited, Peterborough, and reproduced on page 248, *ante*, were inadvertently transposed. That printed on the left is the ammonia compressor, and that on the right the air compressor. Doubtless the error will have been obvious.

COAL DEPOSITS IN NORTHERN IRELAND.—It is announced that geologists and a mining company are examining the prospects for coal mining in Northern Ireland. The most promising locality seems to be in the Coalisland and Lough Neagh area, where five pits were working in 1800. Deposits are also said to exist in Counties Tyrone and Antrim.

CHADWICK PUBLIC LECTURE.—The Bossom Gift Lecture, which is under the trusteeship of the Chadwick Trustees, 204, Abbey House, London, S.W.1, will be delivered at the Royal Sanitary Institute, 90, Buckingham Palace-road, London, S.W.1, on Tuesday, November 18, at 2.30 p.m., by Mr. G. A. R. Sheppard, M.I.C.E., on "Modern Trends in Waterworks Practice." The chair will be taken by Mr. W. J. E. Binnie, M.A., M.I.C.E.

THE LATE MR. P. ROLLESTON.—We regret to record the death of Mr. Patrick Rolleston, vice-president of Aluminium Laboratories, Limited, which occurred at Banbury on Tuesday, September 9, at the age of 44. Mr. Rolleston was educated at Oxford and received his early technical training with the British Thomson-Houston Company, Limited. In 1930, he joined the Aluminium Company of Canada and was for three years in charge of their Shawinigan Falls plant. He was subsequently appointed sales manager of the Northern Aluminium Company and in 1937 joined Aluminium Laboratories, Limited, in Montreal, to take charge of their patent and legal department. During the war he was chief of the light metals section and director of materials supply in the British Air Commission, New York. He returned to England in 1945 to take charge of the research and development laboratories of the Aluminium Laboratories at Banbury.

GAS-TURBINE PROPELLING MACHINERY FOR BRITISH GUNBOAT.

THE possibilities of the gas turbine for use as a prime mover were envisaged many years before the aircraft turbo-jet engine came into prominence, but little was done in this country regarding its development until about 1937, most of the work in the earlier part of this century having been carried out by Continental engineers. From 1937 onwards, however, British engineers showed interest in the gas turbine, particularly as applied to aircraft, and the subsequent successful developments which took place during the war are now widely known. It may be said, perhaps, that it was this success which has led to the revival of interest in the possible application of the gas turbine to industrial purposes and, in particular, to ship propulsion.

This latter application, however, gives rise to certain problems not encountered in aircraft. The marine gas turbine must be able to work continuously for weeks rather than hours, as on aircraft, and at the same time it must show an improvement in fuel consumption over the steam engine, both reciprocating and turbine, and the Diesel engine. The high revolutions of the gas turbine require the use of reduction gearing, and as it does not lend itself readily to the provision of a reverse turbine, some other form of reverse gear must be incorporated, such as the use of electrical drive or reversible-pitch propellers. In light naval vessels, such as gunboats, however, where high speeds are required for limited periods and at short notice, fuel consumption becomes of secondary importance to performance. Furthermore, this class of vessel lends itself more to the use of reversible-pitch propellers, which already have reached an advanced stage of development. The low overall specific weight and size together with the rapid-starting properties of the gas turbine, render it particularly suitable, therefore, for use in this type of craft; furthermore, owing to the fact that it can operate on Pool gas oil, instead of petrol, the fire hazard is reduced considerably. With these points in mind, the Admiralty decided to investigate the practical possibilities of such an application and a gunboat fitted with a gas turbine has now undergone its preliminary trials, being the first naval vessel to be propelled by this type of machinery.

The gas turbine now under trial has been developed for the Admiralty by Messrs. Metropolitan-Vickers Electrical Company Limited, Trafford Park, Manchester, and has been installed in H.M. motor gunboat 2009, a 110-ft. triple-screw craft built by Messrs. Camper and Nicholsons Limited, Gosport. At the outset, it was decided that a jet engine already developed by Metropolitan-Vickers should be employed for the gas-generator portion of the plant. New development, therefore, was confined to the power turbine and its gearing, and to certain modifications to the control system. It was fully appreciated that the performance characteristics of the jet engine were far from ideal for use with power turbines, chiefly because of its somewhat low compression ratio, and it was understood that on this account, the overall efficiency would be affected. It was felt, however, that only by such means could experience be obtained in the operation and control of such a craft within a reasonable time. In the experimental vessel, No. 2009, normal cruising and astern power is provided by two 1,250-brake horse-power Packard internal-combustion engines, which drive the port and starboard propellers through reduction gearing. The gas turbine is fitted between these two engines and, like the Packard engines, is arranged to drive the central propeller through a further set of reduction gears. A general view of the port side of the engine room is given in Fig. 1, on page 272, from which a good idea of the relative sizes of the two different installations can be obtained. The air intake for the gas turbine is situated in the after bulkhead of the bridge superstructure, the air, of course, being drawn in towards the forward end of the vessel. It passes into a chamber beneath the bridge before it is taken into the compressor, so as to ensure that any sea water drawn in through the intake shall settle out.

The gas-turbine plant comprises a gas generator and a power turbine, which is mechanically independent of that used in the gas generator, and is coupled through a reduction gearbox to the propeller shaft. A diagrammatic longitudinal section of the complete unit is given in Fig. 8, on page 276. The gas generator is based on the Metropolitan-Vickers F2/3 engine, as used for aircraft propulsion, consisting of a compressor, a combustion chamber and a turbine for driving the compressor. The compressor is of the axial-flow type, having nine stages and is fitted with aerofoil-section blades of aluminium alloy. The moving blades are fitted into axial serrated slots in a forged aluminium-alloy drum, while the fixed blades are fitted into dove-tail slots formed circumferentially in the stator casing; like the rotor, the casing also is of aluminium alloy. The rotor, which is illustrated in Fig. 9, on page 276, is

provided with a conical extension piece, to the end of which is secured an extension for carrying the turbine disc. The combined rotor and extension piece rotates within two ball bearings, the turbine disc being overhung. The forward bearing acts as a thrust bearing, while the after bearing is fitted into a splined housing which has freedom of movement in an axial direction. These bearings are lubricated by an oil mist, the oil being supplied from two feeds of a small eight-feed, positive-displacement pump. The oil is entrained in air bled from the fifth stage of the compressor and the air, in turn, is directed on to the bearings. This oil, however, is not re-circulated, but the quantity used is quite small, being of the order of four pints an hour, this figure including that used for the power-turbine bearings and auxiliaries. In addition, the bearings are cooled by air taken from the same stage of the compressor and led through the interior of the rotor to ventilating passages formed within both the rotating and stationary bearing housings. Various auxiliaries are fitted to the compressor casing, and these include the fuel pump, the governor, the tachometer generator, the electric starting motor and the lubricating-oil pump. The drive for the auxiliaries is taken from the forward end of the compressor shaft through bevel gearboxes and a vertical shaft.

The combustion chamber is of the annular type, and consists of two concentric containing walls forming an annulus, within which is fitted an annular primary chamber having inner and outer walls. On entering the chamber from the compressor, the air is divided, a small portion entering the primary chamber through a series of holes situated in the upstream end, while the larger portion passes to the inner and outer annuli formed between the primary chamber and the containing walls. Pool gas oil is injected in a finely atomised condition into the primary chamber, the oil being injected against the air stream through 20 fixed-orifice jets. The high-temperature products of combustion in the primary chamber are then mixed with the remainder of the air, which enters the chamber through a number of slots in both the inner and outer walls, resulting in a mixture of a suitable temperature for the turbine inlet. The combustion chamber is made from "Immaculate 5" stainless steel, which has good heat-resisting qualities and a coefficient of expansion equal to that of aluminium alloy.

The turbine for driving the compressor has two stages, the disc which carries the moving blading being made from molybdenum-vanadium steel while the blades are of "Nimonic-80" alloy. A stub shaft is forged integrally with the disc and this stub shaft is splined and locked into the end piece of the conical extension from the compressor drum. Each side of the turbine disc is cooled by air which flows radially outwards from the centre, the air being bled from the compressor outlet.

The power turbine, which, as previously mentioned, is completely separate from the compressor turbine, has four stages, both the fixed and moving blades being made of molybdenum-vanadium steel. The moving blades are fitted into serrations formed in the drum while the fixed blades are dovetailed into circumferential slots machined in the stator casing. The drum is made of molybdenum-vanadium steel while the stator casing is a mild-steel forging. The turbine drum is supported from the central shaft by two dished end pieces, that at the after end being secured rigidly to the shaft, while that at the forward end is connected to the shaft through discs flexible in an axial direction so as to allow for differential expansion of the drum and shaft. The turbine shaft is carried within two ball bearings. The forward bearing is fitted into a spring-loaded housing, which floats axially to deal with expansion and is carried by a fabricated-steel inlet branch through a number of struts of aerofoil section. The after bearing is supported in a similar manner, but is designed to take the axial thrust on the blading; it is fitted in a spherical seating which permits slight angular movement. Both bearings are lubricated and cooled in a manner similar to that employed for the compressor-rotor bearings, the oil being supplied by the same pump, and the interior is cooled by air taken from the fifth stage of the compressor.

The gas-generator outer casing is connected to that of the turbine through a bellows-type expansion joint which can be seen in Fig. 8. On leaving the power turbine, the hot gases pass through an outlet volute of fabricated sheet steel which turns the flow into the funnel.

The reduction gearbox is fitted with single-reduction helical gears which give a reduction ratio of approximately 3·3 to 1; a diagrammatic cross section of the gearbox is shown in Fig. 8. The pinion shaft is hollow and the drive from the power turbine is taken through a flexible quill shaft which passes through the hollow pinion and is attached thereto at the end remote from the turbine; the pinion is carried in roller bearings which are not located axially. A general view of the gearbox is shown in Fig. 4, opposite, while Figs. 5 and 6, on the same page, show the gearbox with the top cover and pinion shaft removed.

GAS-TURBINE PROPELLING MACHINERY.

MESSRS. METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, MANCHESTER.

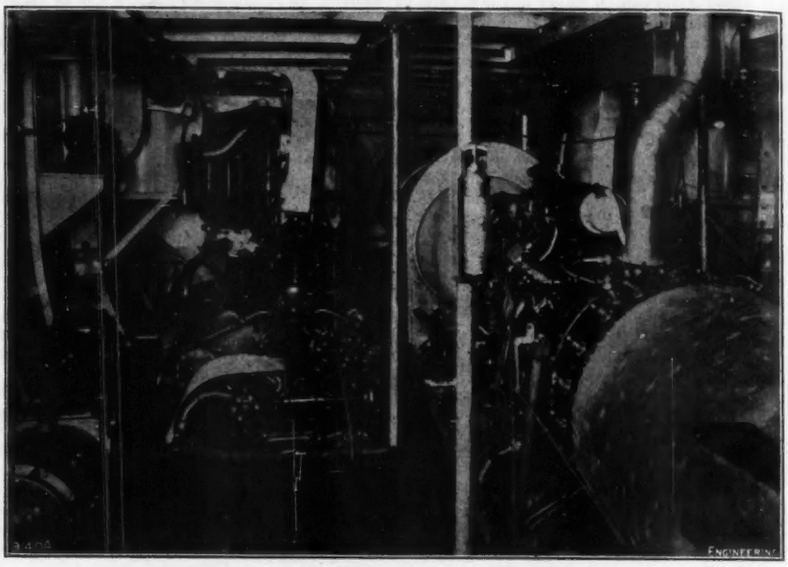


FIG. 1. INTERIOR OF ENGINE ROOM.

Fig. 2.

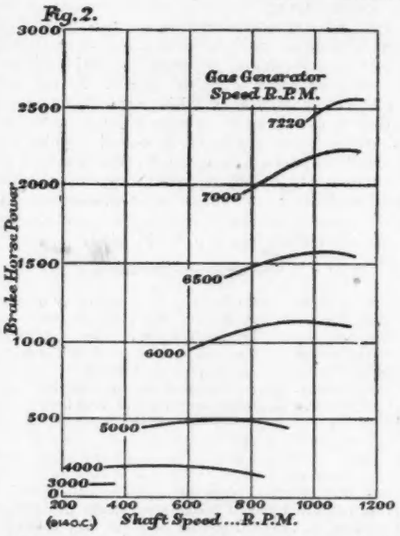
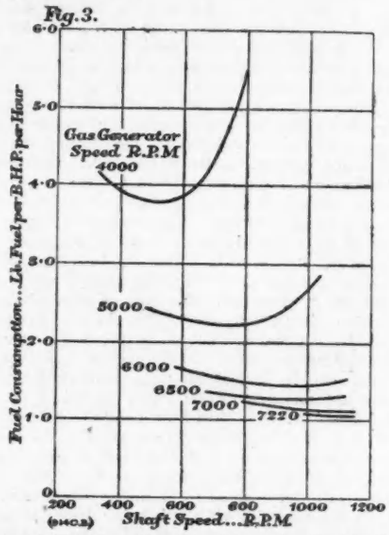


Fig. 3.



It was necessary to provide means by which the gas-turbine propeller could rotate idly when the two Packard engines only were running, in order to avoid motoring losses. For this reason, the gear incorporates a Sinclair self-synchronising clutch mechanism developed by the Hydraulic Coupling and Engineering Company Limited, Isleworth, Middlesex. This device is incorporated in the low-speed gearwheel, which is in two halves with opposed helices; both parts are free to slide along the shaft in an axial direction. Each half of the low-speed gearwheel is fitted with a ring, and each ring is machined with internal teeth, the two rings being fitted to the low-speed gears so that they point towards each other. Between the two rings, and integral with the propeller shaft, are two discs with teeth formed on the peripheries similar to those on a sprocket wheel. When a load is transmitted by the pinion-shaft gears, the axial component of this load, by acting through the helical teeth, causes the two halves of the low-speed gearwheel to move towards each other, with the result that the internal teeth machined in the rings slide over and engage with the external teeth of the discs integral with the propeller shaft, through which the drive is transmitted. One of the toothed rings and both the discs can be seen in Fig. 7, opposite, which is a detailed view of the clutch mechanism. When the turbine is shut down, and the propeller shaft continues to rotate owing to the trailing of the propeller, the opposite action takes place; that is, the helices cause the wheels to slide apart and the toothed rings to disengage. When in the disengaged position, the teeth of the internally-toothed rings pass over a series of spring-loaded pawls fitted immediately to the side of the toothed discs, and these pawls provide the initial resistance that causes the wheels to be brought back into engagement with the shaft when power is restored. The pawls also assist in synchronising the speeds of the shaft and the gearwheel and help to guide the engagement of the rings and the discs; they can be seen in Fig. 7, between the ring and the discs.

In order to avoid continuous duty of the pawls over long cruising periods, and also to prevent the gear from engaging when the vessel goes astern, provision has been made to draw the wheels farther apart, so that the pawls clear the internally-toothed rings. This is accomplished by a system of bell-crank levers and slippers, the slippers engaging with collars formed on the outer faces of the low-speed gearwheel; one of the slippers can be seen in Fig. 6. The low-speed shaft is carried in roller bearings and is provided with a Michel thrust block which can be seen to the left of Fig. 6.

The gear teeth, thrust block, gear bearings and clutch mechanism are supplied with oil under pressure from a Rotoplunge automatic reversing pump, which pumps

GAS-TURBINE PROPELLING MACHINERY FOR GUNBOAT.

MESSRS. METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, MANCHESTER.

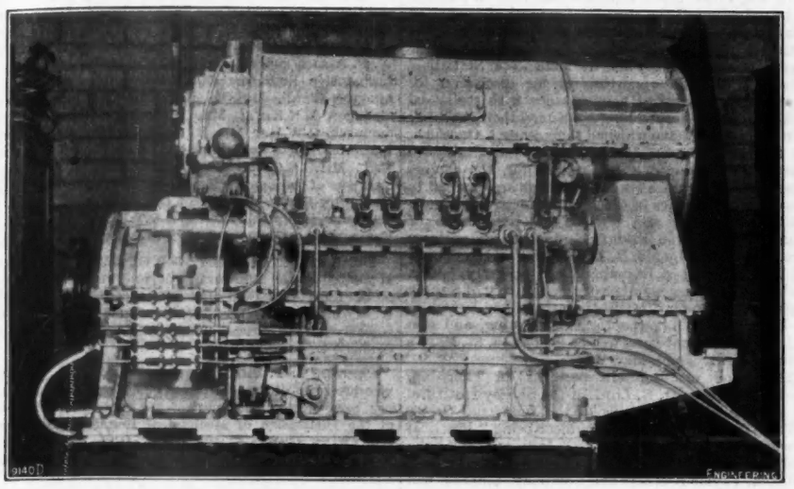


FIG. 4. REDUCTION GEARBOX.

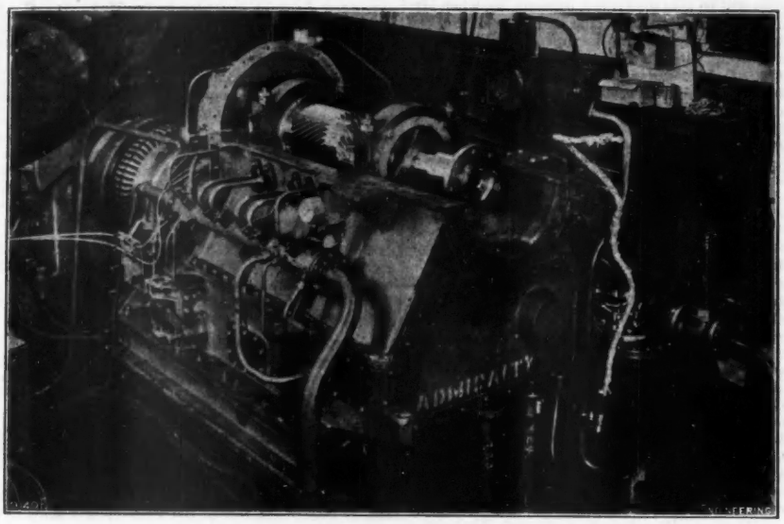


FIG. 5. GEARBOX WITH PINION CASING REMOVED.

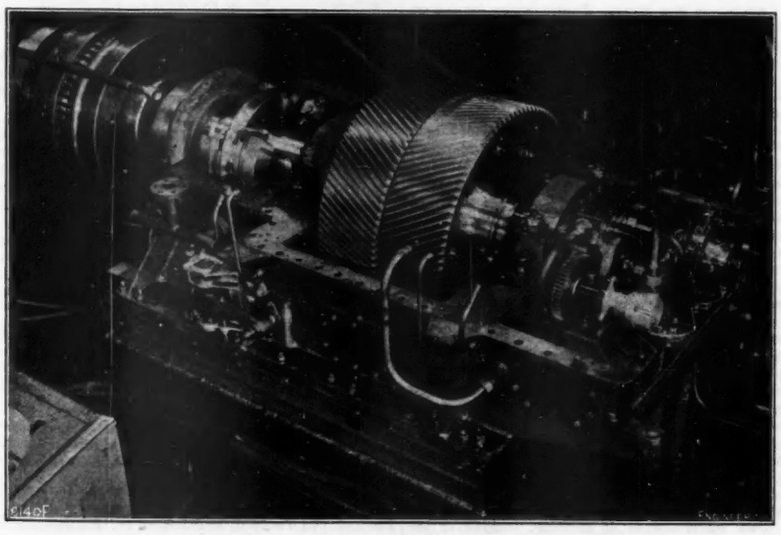


FIG. 6. GEARBOX WITH PINION AND SHAFT REMOVED.

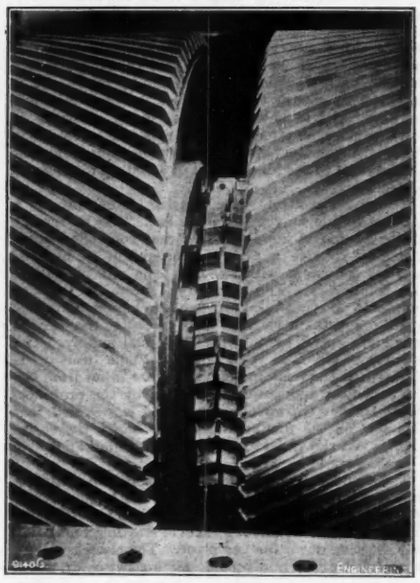


FIG. 7. RINGS FOR ENGAGING CLUTCH.

in one direction only, irrespective of the direction of rotation of the driving shaft. The pump is driven by gears from the propeller shaft and delivers the oil through Auto-Klean strainers to an oil cooler and then to the gear teeth, etc. A thermostatically-controlled by-pass is fitted across the cooler so as to ensure that the oil temperature does not fall below a fixed safe minimum. In addition, a spring-loaded, low-pressure oil trip is incorporated in the circuit which, on operation, shuts off the fuel supply to the gas generator and thereby shuts down the complete plant in the event of the oil pressure falling too low. Furthermore, this trip is arranged so that it cannot be reset unless the clutch mechanism has been moved to the pawls-engaged position. By this means, the needless over-speeding and re-tripping of an unloaded power plant is prevented. When the vessel is cruising and the gas turbine is shut down, the trailing of the propeller rotates the oil pump at a speed sufficient to maintain an oil pressure in excess of the tripping pressure, thereby permitting the gas plant to be started. A hand pump is provided to enable sufficient oil pressure to be established for starting the plant in the case of dock trials.

In view of the fact that the gas plant is out of service and the rotor therefore stationary when the vessel is cruising, there is the possibility of damage being caused to the ball and roller bearings of the plant due to the vibration brought about by the internal-combustion engines. With the gas-turbine propeller trailing, however, the oil drag between the slow-speed shaft and the gear-wheel bushes is sufficient to induce slow rotation of the gear wheels and, therefore, of the power-turbine rotor. The gas-generator rotor, however, will remain stationary and to overcome this a separate inching motor has been fitted which is arranged to drive the rotor through a worm reduction gear. This motor is of $\frac{1}{10}$ h.p. and is visible in Fig. 8, where it can be seen at the top and to the extreme left of the front casing of the compressor.

The power output from the gas turbine is controlled solely by regulation of the quantity of fuel admitted to the combustion chamber of the gas generator. The quantity of fuel delivered and the prevailing atmospheric conditions dictate the speed at which the gas generator will revolve and so determine the rate of gas flow and its temperature and pressure at the power-turbine inlet; these, in turn, determine the output. The gas-generating plant has a minimum speed, known as the idling speed, from which it is possible to accelerate rapidly to full speed. On starting the plant, external means are required to bring the speed up to the self-sustaining speed, which is less than the idling speed. Once the self-sustaining speed has been reached, however, control is effected by regulating the fuel supply alone. In order to bring the plant into operation, the rotor of the gas generator is run up by an electric starter motor to approximately 800 to 1,000 r.p.m., at which speed conditions are satisfactory for firing the

combustion chamber, for which purpose electric ignition is employed. Although some power assistance is received from the turbine once ignition has taken place, by itself it is insufficient to drive the compressor. It is necessary, therefore, to continue to use the motor drive until a speed of approximately 2,000 r.p.m. is reached, at which speed the unit becomes self-sustaining. The motor is then switched off and the unit accelerates to the idling speed under the control of an automatic starting valve. This valve is servo-operated and is designed to ensure that the fuel delivery increases gradually and in phase with the rise of pressure, so that the gas generator accelerates at a safe speed. The time taken to start the gas generator from cold and accelerate it to the idling speed of 3,000 r.p.m. is about 45 seconds.

The main control valve consists essentially of a tapered needle moving in an orifice. The movement of the needle is servo-operated and controlled automatically to give a rate of acceleration as high as possible consistent with freedom from risk of stalling the compressor. The maximum speed of the gas generator is controlled by an overspeed governor which prevents the machine from exceeding the selected maximum speed by throttling the fuel supply. The operating speed of the power turbine usually is dictated by the relation between power input from the gas generator and power absorption by the propeller. An emergency trip governor, however, is provided, and this acts on the fuel supply to shut down the entire plant when the speed exceeds the maximum allowable operating speed by 11 per cent.

The control desk is located in a separate compartment situated immediately aft of the engine room, from which it is divided by a bulkhead; it contains equipment for the remote control of starting, regulating and shutting down the gas plant. The electric starter is provided with a multi-point starting switch, in which is incorporated an indicating lamp for showing when the ignition circuit is closed, while fuel admission over the range from idling to full speed is regulated by a single main-control lever. From the control desk, it is possible to operate and reset the trip which cuts off the fuel and so shuts down the complete plant. In addition, there is a push-button control for the inching motor and the operating lever for the clutch-withdrawal mechanism already described. Electrical interlocks ensure that the starting circuits remain dead until the trip lever is reset and the main-control lever is placed in the idling position. With the trip reset, however, it is possible to accelerate the engine to approximately 1,200 r.p.m. without ignition taking place, thus enabling the mechanical condition of the unit to be checked periodically. Further electrical interlocks ensure that operation of the main switch shuts down and uncouples the inching motor, and that the control-desk trip lever is in the stop position before the inching motor can be started.

Before the unit was installed in the vessel, extensive bench tests were carried out at the works of Messrs. Metropolitan-Vickers. For this purpose the complete unit, comprising gas generator, power turbine and the reduction gearing, was fitted to a fabricated bedplate and coupled to a dynamometer. In view of the atmospheric conditions prevailing in the neighbourhood of the test house, air filters were installed so as to prevent unduly rapid deterioration of the compressor performance by blade fouling. The dynamometer was of the Heenan and Froude Dynamatic type, and it was coupled to the slow-speed gear shaft through a flexible coupling of the Bibby type. The fuel was delivered through a Purolator filter under a small pressure head supplied by an electrically-driven booster pump, the flow being measured by a graduated tank. The lack of mechanical connection between the rotors of the gas generator and power turbine enables the latter to adjust itself readily to the characteristics of the load, and during the tests, a range of power-turbine speeds was examined for various levels of power output from the gas generator. The characteristics of the complete unit so obtained are shown by the curves reproduced in Figs. 2 and 3, on page 272. Fig. 2 shows the output of the power turbine, together with shaft speed, corresponding to various speeds of the gas generator, while Fig. 3 shows the specific consumption and the shaft speed for the same gas-generator speeds. An output of 2,550 brake horse-power was obtained at the designed shaft speed of 1,087 r.p.m. with a gas generator speed of 7,220 r.p.m., and the consumption corresponding to these figures was 1·06 lb. per brake horse-power hour.

It cannot be emphasised too strongly that the installation undergoing trials in M.G.B. 2009 is essentially experimental. Nevertheless, the results obtained augur well for the future of gas-turbine propulsion as applied to small naval craft. The Admiralty are planning already to fit larger gas-turbine machinery into a vessel of the escort type. This machinery has been designed as a marine unit and it is expected that the efficiency and the durability will be better than those obtained with the installation described.

STATISTICAL METHODS IN INDUSTRY.

In the past decade, and more particularly during the recent war years, much attention has been devoted to the introduction of the statistical control of quality in industry, and one of the results of this has been the formation of sub-groups within the framework of the Royal Statistical Society and the Manchester Statistical Society to provide opportunities for discussion for those making their first acquaintance with statistical methods. These groups have continued their activities since the war and have widened their scope. One such, the Industrial Group of the Manchester Statistical Society, has arranged a programme for the coming winter session in which specific evenings are devoted to three of the industries in the Manchester area, namely, textiles, chemicals and steel. The programme of lectures will open on Friday, September 26, with an introductory talk by Mr. R. L. Plackett on the subject of "The Planning of Experiments in Industry." Mr. Plackett is a former member of the Ministry of Supply Advisory Service on Statistical Methods and is now at the University of Liverpool. This meeting, and also the three subsequent ones, will be held at 16, St. Mary's Parsonage, Deansgate, Manchester.

The second meeting will be held on Thursday, October 23, when Mr. E. Lord, of the Shirley Institute, will address a joint meeting of the Industrial Group with the Textile Institute, his subject being "Practical Aspects of Sampling in the Cotton Industry." At the third meeting, on Friday, November 28, Mr. J. Morley, of Messrs. Taylor Brothers and Company, Limited, will speak on "Some Applications of Statistical Methods in the Steel Industry." The fourth, and last meeting, of the series will be held on Friday, January 30, when Mr. K. A. Brownlee, author of the Ministry of Supply Memorandum, "Industrial Experimentation," will give a talk dealing with statistical work in the chemical industry. Further particulars regarding the lectures or other activities of the Industrial Group may be obtained on application to the honorary secretary of the Group, Mr. T. J. Lunt, Research Department, Ferranti Limited, Hollinwood, Lancashire. The honorary secretary of the Manchester Statistical Society is Mr. A. H. Allman, 38, Mosley-street, Manchester, 2.

BOOKS RECEIVED.

Contribution to Victory. An Account of Some of the Special Work of the Metropolitan-Vickers Electrical Company, Limited, in the Second World War. Compiled by FRANK ROWLINSON. Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester 17.

Manual for Process Engineering Calculations. By LOYAL CLARKE. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 6 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30s.]

Carnegie Institution of Washington. Annual Report of the Director of the Department of Terrestrial Magnetism. The Director, The Department of Terrestrial Magnetism, 5241, Broad Branch-road, Northwest, Washington 15, D.C., U.S.A. [Free.]

United States National Bureau of Standards. Miscellaneous Publication No. M184. *United States Patents on Powder Metallurgy.* By RAYMOND E. JAGER and ROLLA E. POLLARD. Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 30 cents.]

United States National Bureau of Standards. Miscellaneous Publication No. M186. *Report of the Thirty-Second National Conference on Weights and Measures at Washington, D.C., September 26, 27 and 28, 1946.* Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 40 cents.]

Canada. Department of Mines and Resources. Bureau of Mines. Publication No. 820. *The Canadian Mineral Industry in 1945.* The Director, Mines and Geology Branch, Department of Mines and Resources, Ottawa, Canada. [Price 25 cents.]

Department of Scientific and Industrial Research. Road Research Laboratory. Technical Paper No. 5. Second edition. *The Grading of Aggregates and Workability of Concrete.* By DRS. W. H. GLANVILLE, A. R. COLLINS and D. D. MATTHEWS. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 6d. net.]

Welding of Plastics. By G. HAIM and H. P. ZADE. Crosby Lockwood and Son, Limited, 20, Tudor-street, London, E.C.4. [Price 21s. net.]

The British Electrical and Allied Manufacturers' Association. Publication No. 135. *British Electrode Classification, Covering Manual Arc Welding Electrodes for Welding Mild Steels.* Prepared and issued in collaboration with the Institute of Welding. Offices of the Association, 36 and 38, Kingsway, London, W.C.2. [Price 1s. net.]

PERSONAL.

We announced on page 178, *ante*, that SIR EUSTACE MISSENDEN had been appointed chairman of the Railway Executive, to be set up under the Transport Act, 1947, and that LORD LATHAM was to be chairman of the London Transport Executive. We now learn that the full-time members of the Railway Executive will include MR. W. P. ALLEN, general secretary, Amalgamated Society of Locomotive Engineers and Firemen, MR. V. M. BARRINGTON-WARD, D.S.O., M.Inst.T., divisional general manager, L.N.E.R.; MR. D. BLEE, chief commercial manager, G.W.R.; MR. R. A. RIDDLES, vice-president, L.M.S.R. Executive Committee, and MR. J. C. L. TRAIN, M.C., M.I.C.E., Chief Engineer, L.N.E.R. Full-time members of the London Transport Executive will include MR. JOHN CLIFF, member of the L.P.T.B.; MR. L. G. HAWKINS, Comptroller to the L.P.T.B., and MR. A. B. B. VALENTINE, railways operating manager, L.P.T.B.

SIR JOHN M. KENNEDY, O.B.E., M.I.C.E., has been appointed by the Minister of Fuel and Power as chairman of the Electricity Commission, to succeed SIR CYRIL W. HURCOMB, G.C.B., whose appointment as chairman of the recently-formed British Transport Commission was announced on page 154, *ante*.

CAPTAIN G. T. SMITH-CLARKE, M.I.Mech.E., a former vice-president of the Institution of Automobile Engineers, has been elected chairman of the Automobile Division of the Institution of Mechanical Engineers, to succeed MR. FRANK G. WOOLLARD, M.B.E., B.Sc. (Eng.), Lond., M.I.Mech.E., the first chairman of the Automobile Division.

MR. BRIAN G. ROBBINS, M.Sc., until recently secretary of the Institution of Automobile Engineers, has been appointed assistant secretary to Dr. H. L. Guy, C.B.E., F.R.S., the secretary of the Institution of Mechanical Engineers. Mr. Robbins has been appointed, in addition, education officer of the Institution. MR. E. B. HAGGERTY has also joined the staff of the Institution. He will handle the general planning of centre programmes and assist with the Automobile Division.

MR. H. SWAIN, M.B.E., A.M.I.Mech.E., formerly technical assistant to the Institution of Automobile Engineers, has been appointed secretary of the Institution of Heating and Ventilating Engineers, 72 and 74, Victoria-street, Westminster, London, S.W.1, in succession to MAJOR N. LONG-BROWN, M.A., LL.B.

MR. I. V. ROBINSON, Wh.Sc., M.I.C.E., M.I.Mech.E., secretary to the heavy-plant sections of the British Electrical and Allied Manufacturers' Association, 36 and 38, Kingsway, London, W.C.2, has been nominated President of the Whitworth Society and will take office in 1948.

MR. W. R. EADIE, formerly assistant secretary of the Manchester regional office of the Federation of British Industries, 21, Tothill-street, London, S.W.1, has been appointed secretary of the south-western region of the Federation at Bristol.

CAPTAIN SIR IAN BOLTON, Bt., O.B.E., has been appointed by the Minister of Transport a member of the British Transport Commission, on a part-time basis.

MR. L. LETHBRIDGE, Deputy Principal Technical Officer (Sea Transport) to the Ministry of Transport has been promoted to be Principal Technical Officer (Sea Transport) in succession to MR. H. KIDD, who retired on September 16. MR. C. S. RIDDELL has been appointed to the post of Deputy Principal Technical Officer (Sea Transport).

MR. GORDON RUSSELL, C.B.E., M.C., Master of the Faculty of Royal Designers for Industry, has been appointed director of the Council of Industrial Design, Tilbury House, Petty France, London, S.W.1.

MR. H. O. PARRACK, A.M.I.Mech.E., M.I.Plant E., has been co-opted a member of the education and examinations committee of the Incorporated Plant Engineers, 48, Drury-lane, Solihull, Birmingham. He is honorary secretary of the London branch.

MR. W. T. HELLABY, A.M.I.E.E., of Messrs. W. T. Hellaby and Company, Limited, Birmingham, has been appointed chairman of the executive committee of the Electrical Contractors Association in place of MR. W. H. WALTON, who has retired after occupying that office since 1932.

MR. L. G. ASTON, A.M.I.E.E., formerly electrical engineer to the Brierfield (Lancs.) Urban District Council, has been appointed electrical engineer at Dorchester. MR. G. E. W. HIRD has been appointed to succeed Mr. Aston, with effect from September 15.

MR. HERBERT E. PAWSON, a director of the Northern British Columbia Power Company, Limited, has been elected President of the Canadian Electrical Association.

MR. C. L. KENT has been appointed London office manager of Messrs. Wardle Engineering Company, Limited, Old Trafford, Manchester, 16. He was assistant manager for some years, and now succeeds the late Mr. H. Gunner.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—The weekly output figures for steel are about 2 per cent. below the maximum capacity. Coal supplies are satisfactory, transport is limited but reasonably good, and the only difficulties relate to the shortage of scrap and pig iron. Scotland probably needs at least 1,000,000 tons of steel scrap per annum. Now dependent almost entirely on home resources, Scotland faces the danger of a cut in steel output unless scrap collections can be increased. The pig-iron position in Scotland is peculiar; a new modern blast-furnace is ready to start, but no coke can be found to feed it. The problem is so urgent that the necessary coke will probably be found somehow, but no definite plan has been announced so far. Coke-making plant would assuredly have been well on the way to relieve the present situation if private initiative had not been stultified by the Government. Meantime, consumers are hard pressed to keep their works in operation, much less to increase their drive to help exports. The proportion of the steel output being consumed on capital goods account leaves only a paltry balance, of perhaps not more than 5 per cent. or 10 per cent., for export in primary or semi-finished forms, which are those urgently needed by Sweden, Finland, and many other countries on whom we are dependent for timber and other vital raw materials.

Scottish Coal.—The output of coal for the past week is estimated at about 437,000 tons, which is 43,000 tons below that for an average good week just before the five-day week scheme started. Having been relieved of her obligations to England and now carrying only a reduced supply quota for Ulster, Scotland, in spite of the decline in output, has been able to supply the high-priority consumers, such as the railways, gasworks and electric power stations, hospitals, and basic industrial undertakings, with sufficient stocks to meet the set target fairly satisfactorily. Reserves are said to be about 8 per cent. better than was the case this time last year, for which the prolonged warm weather has been largely responsible (together with the relief from previous commitments just alluded to), but if output remains at the present low level a serious deficiency of stock this winter is forecast. Export coal is off the market completely. Bunker demands are only partly met, many ships having still to bunker abroad. The wave of strikes which has swept Lanarkshire is receding, and the men are now working quite steadily again.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Pig-iron production has been curtailed considerably by the shortage of coke, due to the "stint" strikes. Similarly, steel production has been considerably reduced by cuts in industrial gas consequent upon insufficient supplies of coke-oven gas from the South Yorkshire gas grid. It had been necessary to reduce supplies of industrial gas in Sheffield by 50 per cent., with a consequent closing down of some melting and heat-treatment furnaces, but last Thursday the gas position became so serious that a 100 per cent. cut had to be made in the case of 120 large industrial users. The settlement of the Grimethorpe dispute made it possible to announce that, on Monday, there would be a 50 per cent. supply to industry. Arrangements were made for all Yorkshire coking coal to be sent to Yorkshire coke-ovens, a course made possible by the arrival of American coking coal at Hull and the decision to send it to the North Lincolnshire coke-works which, in normal circumstances, get their coking coal from Yorkshire pits. Some sections of works which depend upon their own producer-gas plants have been unaffected by the cuts in town's gas, and, similarly, those concerns which had completed the change over to fuel-oil have been able to carry on without interruption. There has been no curtailment of supplies of electricity. Production programmes have been disorganised seriously, and some unemployment has been caused among skilled and unskilled men, in spite of temporary alternative employment being found in some cases.

South Yorkshire Coal Trade.—Strikes at many pits caused a serious dislocation of distribution. Those pits which remained outside the dispute have been drawn upon to make up some of the deficiencies of supply, and it has been necessary to bring into the district supplies from Derbyshire, Nottinghamshire, Northumberland and Durham. Durham coking-coal has been very useful in keeping coke-works operating at slow heats. More vigorous production at opencast sites has been possible owing to the fine weather. Supplies have been adversely affected by holidays at the Doncaster district pits during race week. Some house-coal pits have been working, and outputs from them have been going to gas-works as well as to the domestic market. The make of coke has been reduced considerably and stocks have been drawn upon heavily.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Serious shortage of iron and steel continues to hamper operations at works engaged in the manufacture of commodities wanted in large quantities. Some slight improvement in tonnage distributed is reported, but producers are greatly in arrears with their delivery obligations and any increase in outputs is extremely difficult. At the same time, some expansion in tonnage output is expected in the near future. An increase in the make of pig-iron in the next few weeks is promised. Idle blast-furnaces are to be blown-in as adequate supplies of coke become available. The outlook in regard to fuel still occasions uneasiness, and the possibility of a winter coal famine cannot be ruled out. Conditions still hamper operations at plants engaged in the manufacture of commodities urgently needed for export, as well as for essential home purposes. All classes of steel are in strong demand and producers' commitments are embarrassingly heavy. The pressure for larger deliveries of Tees-side output continue and the rise in prices is unlikely to have any immediate effect on the demand.

Foundry and Basic Iron.—Scarcity of pig-iron high in phosphorus continues to inconvenience users, but is expected to become less acute. The limited local output is promptly absorbed. Basic iron is unobtainable, the whole of the output being retained for the requirements of the makers' own steel-producing plants.

Hematite, Low-Phosphorus and Refined Iron.—Makers of East-Coast hematite have well-filled order books and some contracts extend over periods well ahead; deliveries, however, are steadily maintained. Outputs of low- and medium-phosphorus grades of iron still fall inconveniently short of the users' requirements. Manufacturers of refined iron have a ready sale for their products.

Manufactured Iron and Steel.—Semi-finished and finished iron firms have good orders and steel producers have commitments much greater than they can handle. Makers of steel semies also cannot cope with the requirements of users and further imports of Continental material are awaited. Considerably larger parcels of billets and sheet bars are urgently needed for the re-rolling mills. Maximum allocations of coal have been granted the steel industry and deliveries of finished products have been speeded up to avoid cancellations at the end of the month and to forestall, as far as possible, the higher railway rates which become operative in October. Shipbuilders have benefited considerably by the freer distribution of tonnage. Producers of plates, sheets, joists, sections and rails have full order books.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Figures issued during the past week by the Ministry of Fuel and Power illustrate the gap that still exists between supply and demand in the Welsh mining industry. At the beginning of the year, Mr. Shinwell told the Welsh miners that they should make the weekly figure of 500,000 tons of saleable coal raised their normal output. Following the introduction of nationalisation, a marked effort on the part of the men was apparent, although this was largely offset by the extremely severe weather of last winter. The target was reached and passed on six occasions by the beginning of May. Then, with the start of the five-day week, the target was exceeded on the first two weeks, but since the output has fallen considerably below. From July the production has been further reduced by the staggering of the miners' holidays. The latest figures available showed that, in the week ended August 30, the amount of saleable coal raised in the coalfield was 395,600 tons and the number of men engaged 109,500. Trading conditions were difficult on the Welsh steam-coal market throughout the week. There was a heavy demand from the inland market and the greatest difficulty was experienced in arranging new business for early delivery. The existing bookings by the high-priority home users accounted for the bulk of current productions and what was left found a ready outlet among industrial buyers. There was no sign of any reduction in the demand and consequently the outlook for the export trade was unfavourable. The only coal made available for shipment abroad consisted of limited quantities for delivery to certain users in Eire. Some anthracites were also obtainable for Canada, but otherwise foreign trade was impossible, although several users still showed a keen interest.

INSTITUTION OF ENGINEERING DRAUGHTSMEN AND DESIGNERS.—The appointment of Mr. W. S. Peck as honorary secretary was approved at the annual general meeting of the Institution of Engineering Draughtsmen and Designers, 341, Regent's Park-road, London, N.3, which was held on Thursday, September 11.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—*South Midland Radio Group:* Monday, September 22, 7 p.m., James Watt Memorial Institute, Birmingham. Chairman's Inaugural Address, by Mr. E. May. *Tees-Side Sub-Centre:* Wednesday, October 1, 6.30 p.m., Cleveland Scientific and Technical Institute, Middlesbrough. Chairman's Inaugural Address, by Mr. E. H. Jordan. *Southern Centre:* Wednesday, October 1, 6.30 p.m., Council Chambers, Southsea. Chairman's Inaugural Address, by Mr. D. D. Rayner.

INSTITUTION OF PRODUCTION ENGINEERS.—*Coventry Section:* Monday, September 22, 7 p.m., Technical College, Coventry. "The Effects of the Change in the Horse-Power Tax upon Motor-Car Production Engineering," by Sir Reginald Rootes. *Wolverhampton Section:* Wednesday, September 24, 7 p.m., Wisemore Schools, Walsall. "The Future Development of Machine-Tool Design," by Mr. J. H. Wilkinson. *Liverpool Sub-Section:* Friday, September 26, 6.30 for 7 p.m., Adelphi Hotel, Liverpool. Inaugural Meeting and Dinner.

INSTITUTE OF METALS.—Tuesday, September 23, to Friday, September 26, The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. Annual Autumn Meeting. Tuesday, September 23, 8.30 p.m., Autumn Lecture on "The Metallurgical Resources of Scotland," by Professor G. Wesley Austin. Wednesday, September 24, 9.45 a.m., various papers for discussion. 12.30 p.m., Grand Hotel, Glasgow, Official Luncheon. 2 p.m., various works visits. 7.30 p.m., City Chambers, Glasgow, Civic Reception. Thursday, September 25, 9.45 a.m., various papers for discussion. 12.30 p.m., Grand Hotel, Glasgow, Scottish Local Section Luncheon. 2 p.m., various works visits. 7 p.m., Grosvenor Restaurant, Glasgow, Dinner and Dance. Friday, September 26, all-day excursion on Loch Lomond. For programme, see page 82, *ante*.

INSTITUTE OF REFRIGERATION.—Tuesday, September 23, 5.30 p.m., The Institution of Mechanical Engineers, Storey's-gate, St. James's Park, Westminster, S.W.1. Presidential Address, by Mr. W. S. Douglas.

ROYAL AERONAUTICAL SOCIETY.—*Graduates' Section:* Tuesday, September 23, 7.30 p.m., 4, Hamilton-place, W.1. Discussion on "The Design of Wings," to be opened by Mr. F. Tyson.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Birmingham Branch:* Wednesday, September 24, 7.15 p.m., James Watt Memorial Institute, Birmingham. Presidential Address, by Mr. A. G. Harrison. *London Branch:* Wednesday, September 24, 7.30 p.m., Waldorf Hotel, Aldwych, W.C.2. (i) Presidential Address, by Mr. E. M. Currie. (ii) Film on "Core Blowing," introduced by Mr. J. B. Blakeborough. *Falkirk Section:* Friday, September 26, 7 p.m., Temperance Café, Lint Riggs, Falkirk. "Personal Impressions of American Foundry Practice," by Mr. T. Makemson.

MANCHESTER STATISTICAL SOCIETY.—*Industrial Group:* Friday, September 26, 6.45 p.m., 16, St. Mary's Parsonage, Deansgate, Manchester. "The Planning of Experiments in Industry," by Mr. R. L. Plackett. (See also page 274.)

INSTITUTE OF ECONOMIC ENGINEERING.—*London Region:* Sunday, September 28, 2.30 p.m., Waldorf Hotel, Aldwych, W.C.2. "Reflections on Productive Assessment," by Mr. J. Burgess. *Midland Region:* Saturday, October 4, 2.30 p.m., Chamber of Commerce, Birmingham. "Time Study Allowances," by Mr. S. Walford.

ROYAL UNITED SERVICE INSTITUTION.—Wednesday October 1, 3 p.m., Whitehall, S.W.1. "Higher Training for Combined Command," by General Sir William Slim.

JUNIOR INSTITUTION OF ENGINEERS.—*Midland Section:* Wednesday, October 1, 7 p.m., James Watt Memorial Institute, Birmingham. Annual General Meeting. *Institution:* Friday, October 3, 6.30 p.m., 39, Victoria-street, Westminster, S.W.1. Question and Discussion Evening.

LONDON ASSOCIATION OF ENGINEERS.—Saturday, October 4, 6.30 p.m., Charing Cross Hotel, W.C.2. "Chemistry as a Tool for the Engineer," by Mr. R. A. Rabnott.

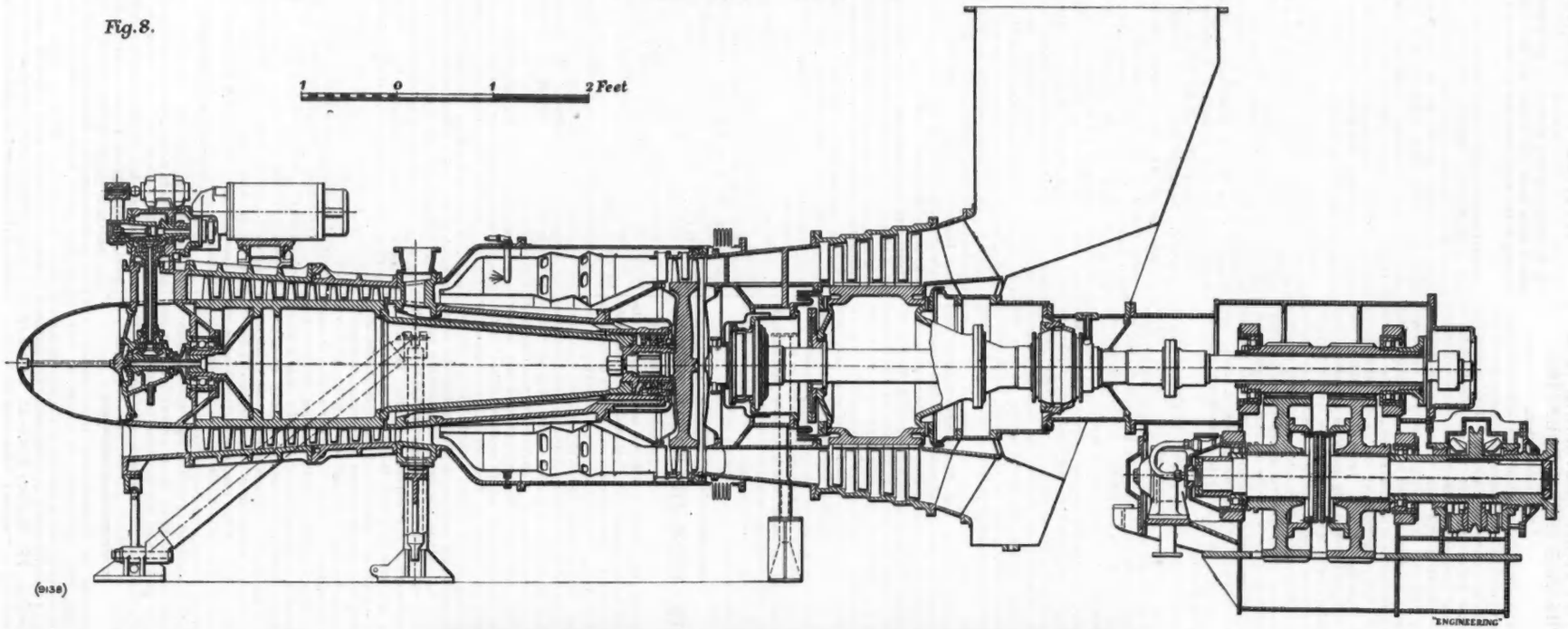
ROLLS-ROYCE ENGINES IN CIVIL AIRCRAFT.—A brochure, which gives some conception of the services rendered by Rolls-Royce aero engines to civil aviation since the war, has recently been published by Messrs. Rolls-Royce Limited, Derby. After giving statistics of the mileage flown by Merlin engines in commercial use, the brochure describes the service, repair and spare-part facilities which have been organised throughout the world for air-line operators using Rolls-Royce aero engines. A double-page coloured map, showing air routes and the situation of repair bases, spare-part depots and service-engineers' stations, is included.

GAS-TURBINE PROPELLING MACHINERY FOR GUNBOAT.

MESSRS. METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, MANCHESTER.

(*For Description, see Page* 271.)

Fig. 8.



THE AUTOMOBILE DIVISION OF THE INSTITUTION OF MECHANICAL ENGINEERS.—The first annual general meeting of the Automobile Division of the Institution of Mechanical Engineers' will be held at Storey's-gate, St. James's Park, London, S.W.1, on Tuesday, October 7, 5.30 p.m.

THE CHEMICAL SOCIETY.—An allocation of grants from the research fund of the Chemical Society will be made in November next. Applications, on forms obtainable from the Society, must reach the General Secretary, The Chemical Society, Burlington House, Piccadilly, London, W.1, not later than November 1. The donation of the Goldsmith's Company to the Society is intended chiefly for research in inorganic and metallurgical chemistry, and the Perkin Memorial Fund is applied to research connected with problems affecting the coal-tar and allied industries. Applications from Fellows of the Chemical Society will receive first consideration.

INTERNATIONAL ELECTRICAL AND PHOTOMETRIC UNITS.—On page 55, *ante*, we announced the changes in the international electrical and photometric units, which are to be made on January 1, 1948, in accordance with decisions taken by the International Committee of Weights and Measures. A circular issued by the National Bureau of Standards, Washington, D.C., gives a short account of the development of the agreements, which led up to this decision, and points out that the increasingly close connection between physical constants in various fields has emphasised the desirability of using practical units, which are consistent with the fundamental mechanical units.

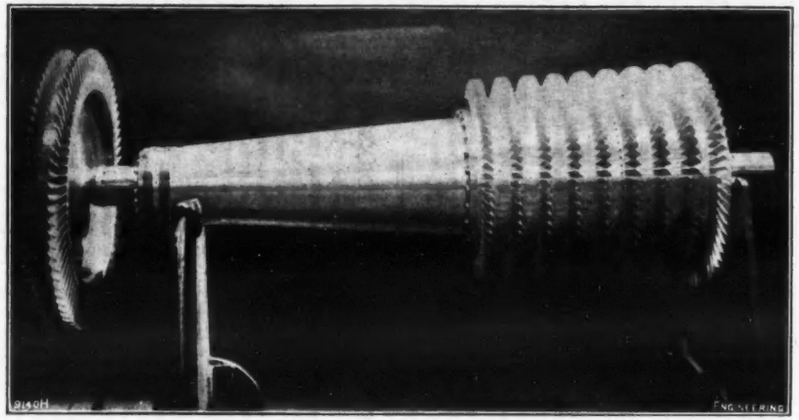


FIG. 9. ROTOR ASSEMBLY FOR GAS GENERATOR.

GENERATION OF ELECTRICITY.—The official returns rendered to the Electricity Commissioners show that 2,767 million kWh of electricity were generated by the authorised undertakings in Great Britain during August, compared with 2,847 million kWh in the corresponding month of 1946, a decrease of 80 million kWh, or 2·8 per cent. During the first eight months of 1947, the total electricity generated was 27,289 million kWh, compared with 26,093 million kWh during the corresponding period of 1946, an increase of 1,196 million kWh, or 4·6 per cent. The total quantities sent out during August, 1947, and August, 1946, were 2,603 million kWh, and 2,680 million kWh, respectively, a decrease of 77 million kWh, or 2·9 per cent. During the first eight months of 1947, the total amount of electricity sent out was 25,743 million kWh, compared with 24,604 million kWh in the corresponding period of 1946, an increase of 1,139 million kWh, or 4·6 per cent.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

SUBSCRIPTIONS.

"ENGINEERING" may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance:—

For the United Kingdom and all places abroad, with the exception of Canada	£4	10	0
For Canada	£4	5	0

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for inserts, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, SEPTEMBER 19, 1947.

VOL. 164. No. 4260.

THE NATION'S EXPORT PROGRAMME.

THE importance of the role for which the engineering industry has been cast in the Government's export programme for 1948 is clear. According to the official document, which was issued at the end of last week, it is intended that by the middle of next year the value of the monthly output of machinery for export shall reach 19,500,000*l.*, rising to just over 22,000,000*l.* by the end of the year. These figures represent percentage increases of 224 per cent. and 254 per cent., respectively, over the figures for 1938. Similarly, it is proposed that the value of the monthly export of road and rail vehicles shall reach 18,320,000*l.* by the middle of 1948 and 22,400,000*l.* by the end of that year, these figures representing increases of 258 per cent. and 316 per cent., respectively, over that for 1938. Exports of electrical apparatus are to reach 4,200,000*l.* and 4,300,000*l.*, respectively, on the two dates, the corresponding increases over 1938 being 210 per cent. and 215 per cent. The total monthly value of the exports aimed at is 114,000,000*l.* by the middle of 1948 and 131,650,000*l.* by the end of that year, or 143 per cent. and 164 per cent. above the 1938 figure. Of these totals the proportions represented by the engineering categories mentioned above are, in round figures, 37 per cent. in each case. Owing to the general rise in prices during the past decade, the increases in volume are not so large as those in value. They are, however, large enough, as is shown by some figures given in *The Times*, which may be quoted here. According to these, it will be necessary, by the middle of 1948, to increase the volume of machinery produced by 50 per cent. over that manufactured in the second quarter of the present year, and by 72 per cent. at the end of 1948. On the same basis, the volume of vehicles will have to be increased by 49 per cent. and 83 per cent. and the volume of electrical apparatus by 44 per cent. and 45 per cent., respectively. It is clear, therefore, that the task before the industry, if not overwhelming, is of very considerable magnitude, and that to accomplish it will demand the full energies of all concerned, as well as the reduction of all types of friction to a minimum.

That, however, does not complete the tale. As Sir Stafford Cripps pointed out in a speech to representatives of both sides of industry at the Central Hall, Westminster, on Friday, September 12, one of the special difficulties in fixing such a target is that, owing to the shortage of foreign exchange, a number of countries are following Britain's example and are reducing the imports of certain types of product. They are, in fact, concentrating on the acquisition of capital goods with a view to building up their own industries. The consequence is that it is becoming harder to find markets for some of the less essential British products, such as radio sets and motor cars. In a word, therefore, Britain must expend additional energy in selling as well as in production. This may, however, be made a little easier by the general shortage of dollars, as a consequence of which countries, which have been importing from the western hemisphere, will be encouraged or even obliged to come to Britain for goods. It must be part of the British policy, therefore, to be prepared to change from one export to another in accordance with the demands that are made at any particular time. The corollary, as it appears to us, is that the Government, while continuing to lay down the broad lines of approach to the solution of the many problems inherent in their policy, should surrender to industry, and to those in industry who have the knowledge of actual and potential markets, the task of working out details in an atmosphere freed as far as possible from unnecessary and irritating controls. Only in that way can the essential flexibility of action be maintained.

The majority of readers of ENGINEERING, however, will be concerned with the production rather than the selling side of the problem. This, it is hardly necessary to point out, bristles with its own peculiar difficulties. As Sir Clive Baillieu rightly said, at the meeting to which reference has just been made, the question that arises immediately in this connection is whether sufficient coal and power, materials and labour will be obtainable to make it possible to run the factories efficiently. He expressed the hope in future that industry would be given the first claim on fuel supplies of all kinds instead of being, as at present, the residuary legatee. He also hoped that steps would be taken to improve the morale, output and costs of industry by removing those shortages in materials which had recently mitigated so greatly against the exertion of continuous effort.

In our opinion, it is also equally necessary that sufficient equipment should be provided to ensure that the material is turned into finished products as speedily and efficiently as possible. For that reason we view with some alarm Sir Stafford's statement that, of the additional exports, some substantial part must take the form of capital goods; not because the supply of such goods is to be deplored in principle, but because their diversion to foreign markets is apparently to mean "a substantial postponement of the flow of new machinery and equipment to our own industries." If, however, the export not only of engineering but of other products is to be increased, additional machinery will be urgently needed in Britain's own factories, further generating plant will be required in the power stations, and fresh endeavours will be necessary to restore the transport system to its pre-war state of efficiency without delay. If all these tasks are not accomplished, considerable obstacles will be placed in the way of increased output, and the targets envisaged will probably not be attained.

As regards materials, the most important is, of course, coal, since without it production of any kind is impossible. The present situation would also be much alleviated if a surplus over and above the domestic requirements were available for export. Of that, however, there seems no likelihood in the immediate future and the best that can be hoped is that during the coming months industry will receive sufficient supplies to ensure the success of the new programme. On that point the opinion of the Ministry of Fuel and Power is at present optimistic, but the experiences of last winter are hardly likely to remove entirely the anxiety of industry on that score. In fact, so long as those who are primarily responsible for winning British coal fail to realise to how large an extent the future prosperity of the country depends upon their endeavour—or, realising it, still insist on putting their selfish interests before those of the nation—the chances that industry will be able to do all that is required of it are

dubious in the extreme. Sir Stafford passed all too lightly over this difficulty; but, of course, the supply of coal does not fall within the orbit of his department.

The question of providing the labour necessary for the production of the increased output that is being planned threatens to prove hardly less difficult of solution than the supply of coal. Upon this subject an early statement from the Minister of Labour is promised, and until that is made detailed comment must be withheld. It is well known, however, that the Government are reluctant to adopt any form of industrial conscription and have already retreated from the heroic position they recently took on this question. How labour can be siphoned away from the less necessary industries to those which are more essential is more than a little difficult to see, especially when the former provide greater attraction in the shape of better working conditions and higher financial rewards. To raise wages in essential industries would be a dangerous solution, since inevitably it would be followed by a general demand for further increases, raising costs all round and making overseas markets still more difficult to enter and develop. The problem is not made easier by the attitude of the trade unions to anything which offends against the rigid dogmas upon which they have built up their present strength and influence. It is clear, however, that, unless their attitude is modified, the new plan cannot be made to work. Their leaders, we believe, realise well enough that, unless it can be made to work, the reactions for themselves as well as the effect on the national well-being will be most unpleasant.

Sir Clive Baillieu has pledged industry's full support of this latest official programme, but has rightly pointed out that its success depends upon the willingness of the Government to make it possible. One important way in which this could be done is, at least temporarily, to replace tactics by grand strategy on the one hand and, on the other, to supplement what is still vague and general with sufficient detail to enable a beginning to be made on the right lines. It may be recalled that the first outcome of "the review of the economic programme," which was foreshadowed by the Prime Minister at the beginning of August, was a cut in imports amounting to some 228,000,000*l.* in an attempt to close the gap of 600,000,000*l.* in the adverse balance of payments. This was followed by a statement that the net output of British agriculture was to be increased by 20 per cent., while the export plan, which we have discussed above, forms the third instalment towards implementing a general policy which, it must be assumed, is being formulated to overcome the nation's difficulties. There are, however, a number of matters still requiring consideration and adjudication. These include inflation, the balancing of the budget, the control of expenditure, and the reduction of the Civil Service. With the last is bound up the whole question of the machinery of Government, to which particular attention is given in the fifth report of the Select Committee on Estimates, published this week, dealing with "Organisation and Methods and Its (*sic*) Effect on the Staffing of Government Departments."

Although the method of defeating a crisis by instalments has perhaps been inevitable in the present situation, it has grave disadvantages, one of the gravest of which is the uncertainty which it creates in the public mind. Imports, agriculture, exports, national finance and Government machinery are not separate entities, but are all parts of one national structure, and alterations or disturbances in one of them affect the working of the whole to a greater or less extent. What is required, therefore, is an overall strategic plan which will embrace all the relevant factors, some of them mutually antagonistic, and will enable an all-embracing economy to be formulated, which can be utilised to restore our national prosperity. In proverbial phrase, the Government should give the people an opportunity of seeing the wood as a whole; and not expect them to be content with a view of individual trees, the properties of which may cause a false picture to be obtained. There is, however, little time to lose.

ENGINEERING ECONOMICS.

In planning an engineering work of any kind, it is necessary to take account not only of the capital expenditure involved but of the cost of operation, maintenance, depreciation, obsolescence and various other factors. Engineering projects, however, are in no way peculiar in this; it applies to most financial transactions. Although few people are likely to draw up a financial balance sheet before buying a pair of shoes, most are conscious that first cost has some relation to life and maintenance, and that the cheapest article may not be the best investment. Another non-engineering example is furnished by stock purchases by retail shops. Long experience and trained judgment are necessary in deciding to what extent the original cost is affected by the rate of turnover likely to be achieved and the possibilities of a proportion of the purchase ultimately proving unsaleable or saleable only at prices possibly lower than the original cost. Fundamentally, the problems of activities of this kind are financially similar to those encountered in designing and building any engineering work but are usually much simpler. The number of factors which have to be taken into account in the planning of, say, a new railway, is very large and the whole project, from an economic point of view, may be one of great complexity.

Much importance attaches to proper understanding of the economic bases of engineering projects, since almost all capital works are engineering works. The building and equipment of a textile mill is an engineering job and demands careful analysis of the relation between capital costs and running costs. In a case of this kind, the overall economic problem includes considerations relating to the cost and quality of the material manufactured, which can only be dealt with by textile experts, but to a very large extent the allocation of capital expenditure is an engineering matter. A well-known example, in the purely engineering field, in which the relation between capital and running expenditure is of the first importance, is furnished by the case of an electric power station. High efficiency and low fuel consumption may be attained by installing plant of the most modern type, but this is more costly than machinery of lower efficiency and if the load factor of the station is likely to be relatively poor, it may well be that economic analysis will show that the cheaper plant of lower efficiency will generate current more cheaply than if full advantage is taken of the possibilities of boiler and turbine development.

This particular problem of power-station design has been complicated by the rise in the price and the deterioration in the quality of coal, but these considerations, while complicating economic analysis, have made it all the more necessary. Consulting engineers and others who are engaged in the design of power stations are entirely aware of the importance of the relation between capital and running costs, and of many other items such as the relative weight to be given to the advantages and disadvantages of alternative sites, but it is probable that most engineering students do not realise that the whole basis of their future practice will be economic. They are naturally interested in the technical side of their work and give it first place, as it is their duty to do. If they are earnest and good workers they probably also find that their scientific studies engross the whole of their attention. It is desirable, however, that they should have a general appreciation of the cardinal importance of the economic aspect of their work, and in order to assist in the attainment of this general appreciation, the Institution of Civil Engineers has published a booklet* dealing with the elements of the matter. Most engineering students will have little time to devote to works on accountancy, but few should have difficulty in finding time at least to read this 48-page pamphlet. It is intended for study, but mere reading will create a background knowledge of its subject. It contains many worked-out examples illustrating the bearing of economic considerations on technical design and some of these may well be found capable of direct application when student days are over.

The booklet begins with a series of definitions of accountancy terms, such as asset, redemption, present value, etc. This is a valuable feature. The late Dr. Rosenhain once said that he thought the difficulty some mechanical engineers experienced in following the arguments and conclusions of metallurgists was due to a lack of precise understanding of the meaning of the special terms which they used. It is probable that something of the same kind operates in the field of economics. Any engineering student, and some practising engineers, who suppose that they have a clear idea of the meaning of the term "value" when applied to an engineering work, might find themselves at a loss if they were required to give specific meanings to the terms "residual value," "scrap value" and "market value." These things are matters for accountants, but it is desirable that engineers should know what accountants are talking about.

In view of its source, the pamphlet is naturally directed to civil engineering students, but those concerned with other branches of the profession will find it equally valuable. Civil engineering is concerned with the design and construction of dams, docks, bridges and other structures which may be described as fixed permanent works, but the civil engineer is required to have knowledge of the mechanical and electrical equipment which is required both in their construction and operation. An important consideration in the design of a dam is the determination of the method by which it is to be built. There are many different ways of carrying out excavation and of moving spoil and building material, and the designer is required to have knowledge of the relative advantages and disadvantages of the various alternatives. It is not the business of civil engineers to design drag-line excavators, but they may well require knowledge of their cost, efficiency and life in deciding the layout of a project involving much earthwork. It may be necessary to co-operate with a consulting mechanical engineer and with the plant manufacturers, but the point is that the qualifications of the mechanical equipment involved must be taken into account in working out the economic balance sheet of the project. In some cases, technical considerations may leave little choice of method, but that will not eliminate the necessity for economic analysis.

An example which is worked out in considerable detail in the pamphlet well illustrates this interlocking of civil and mechanical considerations. It is postulated that a single-line standard-gauge pioneer railway is to be constructed between two places separated by a ridge of high ground. Two schemes are possible, consisting either of a tunnel two miles long and taking two years to construct, or a detour line, six miles long, which could be built in a year. The cost of the first project is 247,120*l.*; and of the latter 151,000*l.* The estimated pay load of the line is 547,500 tons per year in one direction and 219,000 tons per year in the other. Depreciation works out at 186*l.* per mile for the line in the open country and 316*l.* per mile for the line in the tunnel. Assuming the line operated by steam locomotives, with coal at 30*s.* per ton, the running cost, covering fuel, wages and rolling-stock maintenance, works out at 610*l.* per year for the tunnel and 2,584*l.* per year for the alternative route. The total annual charges, with interest on capital and finance during construction at 3 per cent., are 10,080*l.* for the tunnel line and 9,763*l.* for the open line. This result is based on the immediate traffic available, but as the capacity of the line is at least double this, and as 100 per cent. increase in traffic would result in an increase of only 70 per cent. in running costs, the relative positions of the two lines might be expected to be reversed in the future. With such a growth of traffic the annual charges for the tunnel line would only be 10,507*l.*, against 11,572*l.* for the longer route. The decision on which scheme to adopt in this hypothetical case would thus ultimately rest on considerations determined by future traffic, which might not fall within the province of the consulting engineer, but the analysis prepared by him would be of great value to the traffic authorities.

* *An Introduction to Engineering Economics for Civil Engineering Students.* The Institution of Civil Engineers, Great George-street, Westminster, S.W.1. [Price 1*s.*]

NOTES.

JOHN COCKERILL OF SERAING.

A CEREMONY which, so far as we are aware, is without precedent in the history of industrial pioneering, took place at Liége on Sunday last, September 14, when the remains of John Cockerill, who is generally regarded as the founder of the Belgian iron and engineering industries, were transferred from the cemetery of la Glacière to the Place Communale at Seraing, the suburb of Liége where the works which he established are still situated. The ceremony was honoured by the presence of the Prince-Regent and the large concourse included Mr. Delattre, the Belgian Minister of Fuel; Mr. Troclet, Minister of Labour; Mr. Lepage, President of the Association des Ingenieurs Sortis de l'Ecole de Liége, who have organised the International Exposition of Scientific Research and Industrial Control, now being held in that city; and many other prominent engineers and industrialists. Mr. Albert Neef de Sainval, directeur-général of the Société Anonyme Cockerill, delivered an address in which he recalled how, in 1817, when Cockerill started his first blast-furnace, Seraing was little more than a village; its growth to one of the major engineering centres of Europe was directly attributable, not only to his energy and skill, but to the foresight which led him to stress continually the need for scientific research. At that time, the laws of mechanics were not widely appreciated, other than as general principles formulated by the great philosophers of the Eighteenth Century; laboratories, still very rudimentary, were devoted to abstract rather than practical studies. Cockerill provided the initial impulse, though it was not until the time of King Albert that science and industry really began their present close collaboration. John Cockerill's personal direction of his works was relatively short, considered in relation to its long history; he died in Warsaw in 1840, and was buried there. It was not until 1867 that his body was transferred to la Glacière, in the centre of the town which owed so much to him. During the recent war, the cemetery suffered heavily from enemy bombardment, and the damage to Cockerill's tomb led the local authorities to decide to transfer his remains elsewhere. The spot chosen is at the base of the monument erected in the Place Communale in 1871. In a world which so often affects to regard its captains of industry in anything but a favourable light, it is refreshing to find so whole-hearted a tribute paid to a pioneer of engineering by all classes, from Royalty to the workpeople who attended in their thousands: and it is tempting to see some connection between this (to the English mind) "Victorian" atmosphere and the prosperity which Belgium obviously is enjoying.

EXTENSIONS TO GENERATING PLANT.

It is announced that the Central Electricity Board have prepared programmes of generating plant extensions for the years 1951 and 1952. These provide for the installation in selected stations, and 14 projected new stations associated with the grid, of 3,923·5 MW, at an expenditure of nearly 190,000,000*l*. It is hoped that 2,306·5 MW of this total will be in commission by the winter of 1951 and the remainder a year later. Hitherto, it has been the practice of the Board to plan for the additional generating plant required to meet the country's electricity needs four years ahead, and, as far as possible, to arrange for work on new stations to be begun five years ahead. In view of the longer periods now required for the completion and commissioning of new plant, the Board have extended their plans to cover the fourth and fifth years, in respect of both extensions and new stations. At the present time, work is in progress on earlier extension programmes, which provide for the installation of about 6,000 MW of additional plant, including 17 new generating stations, by the winter of 1950, so that the total to be installed between the present date and the winter of 1952 is nearly 10,000 MW. Since January, 1, 1947, arrangements have been made for the installation of one 60-MW set and one 540,000-lb. boiler in the Portobello station of the Edinburgh Corporation. A 60-MW set and two 360,000-lb. boilers are also to be installed in the Carrington station of the Manchester Corporation, and in the Chaddeston station of the Oldham Corporation. The Skelton Grange station of the Leeds Corporation is to be extended by one 60-MW set and one 550,000-lb. boiler; the Stourport station of the Shropshire, Worcestershire and Staffordshire Electric Power Company by one 60-MW set and one 525,000-lb. boiler; the Staythorpe station of the Derbyshire and Nottinghamshire Electric Power Company by one 60-MW set and three 240,000-lb. boilers, and the Meaford station of the North-West Midlands Joint Electricity Authority by two 60-MW sets and four 360,000-lb. boilers. The new stations of the Central Electricity Board at Keadby is to be equipped with three 60-MW sets and three 550,000-lb. boilers, and that of the Newport Corporation at Usk Mouth with six 60-MW sets and twelve 360,000-lb. boilers. Two 60-MW sets and four 360,000-lb. boilers are also to be installed in the Littlebrook station of the Kent Electric Power Company, in the Bankside station of the City of London Electric Light Company and in the Carmarthen Bay station of the Llanelly and District Electricity Supply Company. Two 50-MW sets, one 45-MW set, one 40-MW set, twelve 30-MW and three 20-MW sets are being installed in various other stations.

ACCIDENT ON S.S. "REINA DEL PACIFICO."

A regrettable accident, which resulted in the deaths of 23 and the injury of 30 persons, occurred, as the result of a serious explosion on the liner Reina del Pacifico, of the Pacific Steam Navigation Company, on Thursday, September 11. At the time, the vessel, which had been reconditioned, by Messrs. Harland and Wolff, Limited, of Belfast, after war service, during which she steamed about 500,000 miles, was undergoing trials and was about nine miles north of Copeland Island, at the entrance to Belfast Lough. The Reina del Pacifico was completed in 1931 by Messrs. Harland and Wolff for the owners' service between Liverpool and the West Coast of South America. She is 550 ft. long between perpendiculars, with a moulded breadth of 76 ft. and a moulded depth of 44 ft. Her gross tonnage is 17,707 and her displacement 23,500 tons. The propelling machinery consists of four Harland-B. and W. single-acting trunk-piston engines with airless injection, each unit having 12 cylinders of 24·8 in. bore with a piston stroke of 47·24 in. Under service conditions, these engines develop 18,000 shaft horse-power, giving a speed of 18 knots. The engines are supercharged on the Büchi system and the exhaust is utilised in two 4,000-lb. waste-heat boilers. The vessel is also equipped with four 350-kW Diesel-electric generators, which supply direct-current at 220 volts for auxiliary purposes. The main engines are manœuvred by compressed air, which is stored in four reservoirs. These reservoirs are charged by two compressors, each of which is driven by a 180-h.p. electric motor running at 250 r.p.m. There is also a steam-driven compressor for emergency use. The whole of the deck machinery is electrically-operated. We understand that the Minister of Transport has ordered a formal investigation into the explosion.

JOURNAL OF MECHANICS AND APPLIED MATHEMATICS.

A new publication, to be called *The Quarterly Journal of Mechanics and Applied Mathematics*, has been established to deal with classical mechanics. The topics which it will cover will include hydrodynamics including aerodynamics, sound and dynamical meteorology; elasticity and plasticity; numerical methods, including calculating machines and relaxation methods; non-linear dynamics; ballistics; and classical electro magnetism, including the propagation of electric waves in space and in wave-guides. We are informed that the co-operation of a number of eminent British investigators in these fields has been secured, and that they will form, with Professor S. Goldstein, M.A., F.R.S., Professor R. V. Southwell, M.A., M.I.Mech.E., F.R.Ae.S., F.R.S., Professor Sir Geoffrey I. Taylor, F.R.S., and Professor G. Temple, D.Sc., F.R.S., the editorial board of the new journal. The business connected with the periodical will be conducted by two executive Editors, Dr. V. C. A. Ferraro, of University College, Exeter, and Dr. G. C. McVittie, of King's College, London. The Oxford University Press has undertaken to publish the journal, and it is intended to issue the first number in April, 1948. Papers on the subjects enumerated above will be welcomed, and authors wishing to send contributions for one of the early issues should dispatch them before December, 1947, addressed by name, to one or other of the executive editors, at King's College, Strand, London, W.C.2.

COAL OUTPUTS AND STOCKS.

The decision taken at the beginning of the summer season to issue monthly, instead of weekly, statements of coal production has now been altered by the Ministry of Fuel and Power. The latest of these statements shows that, during the week ending Saturday, September 6, the saleable output of deep-mined and opencast coal attained the figure of 3,620,700 tons, compared with 3,784,000 tons in the corresponding week of 1946. Provisional figures put the output for the week ended Saturday, September 13, at 3,581,300 tons. During the week ended Saturday, September 6, it is estimated that 248,000 tons were lost owing to disputes, the corresponding figure for the week ended Saturday, September 13, being 286,000 tons. Unfortunately, these production figures are still well below the revised target for weekly production of deep-mined coal, which was recently announced by the Prime Minister to be at least 4,000,000 tons from September 1 onwards; and indicate that the unofficial estimates of 195,000,000 tons for the year will no longer be attainable. On the other hand, the stock position has improved, the amounts held on Saturday, September 13, by the gas undertakings being 2,398,900 tons, compared with 1,379,000 tons a year ago, while on the same date electricity undertakings had 3,907,800 tons, compared with 1,888,000 tons. The stocks held by the railways did not, however, show so much improvement, the figure on Saturday, September 13, being 530,000 tons, compared with 486,000 tons a year ago. Merchants' stocks of house coal were 1,487,000 tons on the same date, compared with 1,514,000 tons a year previously, but the total distributed stocks were 13,147,000 tons against 9,707,000 tons. The number of employees had increased from 698,400 to 717,600, and the overall output per man-shift from 1·03 tons to 1·05 tons.

LETTERS TO THE EDITOR.

THE MEANING OF MASS.

TO THE EDITOR OF ENGINEERING.

SIR,—An elementary text-book of statics and dynamics, by means of which I was introduced to the subject about 45 years ago, is still being used by students to-day. It was first published in 1890, revised in 1906, and was reprinted without further material change as recently as 1939. An almost equally venerable text-book of mechanics was reprinted in 1941. These books define the mass of a body as being the quantity of matter in the body. Since a body is said to be a quantity of matter, it seemed to me that the foregoing definition was equivalent to saying that: "The mass of a quantity of matter is the quantity of matter in the quantity of matter."

Not finding this particularly helpful, I looked elsewhere for a more satisfactory definition. Goodman, in his *Mechanics Applied to Engineering*, referred his readers to Karl Pearson's *Grammar of Science* for a rational definition of mass. Here I found the statement that mass "is a mere number representing a ratio of accelerations." This seemed to be a product of Pearson's subjective idealism, according to which matter consists solely of sense impressions; a doctrine which may be difficult to confute, but which did not appeal to me as being rational. The next book I turned to was Worthington's *Dynamics of Rotation*, in which I found the word "mass" used as being equivalent to "inertia." A little later, having an examination to pass, I abandoned my quest and memorised the definition which seemed most likely to see me through. In this, no doubt, I resembled the students of whom

T. H. Huxley said: "They learn to pass, not to know; and outraged science takes her revenge. They do pass, and they don't know."

More recently, my interest in the subject of mass was revived by progress in nuclear physics. This led me to examine 30 modern books on mechanics and physical science in an engineering library. Of these, 25 define mass as "quantity of matter." One of the remainder states that mass is the name given to inertia when expressed as a measurable quantity, while another, by Einstein and Infeld, asserts that "matter represents mass," and "energy represents matter." A third, by Max Born, says that "energy and mass are just different names for the same thing." In addition to all this, I learned that, if the speed of a moving body increases, its mass increases as well; also that there are various aspects of mass, indicated by such terms as rest mass, inertial mass, transverse mass, longitudinal mass, electro-magnetic mass, and mass defect.

My object in writing this letter is to put in a plea for the students of to-day, who will be the engineers and physicists of to-morrow. It will be conceded, I think, that text-books compiled nearly half a century ago, and since reissued without material revision, are not a promising medium for leading up to current conceptions of mass, matter and energy, however useful they may be for cramming purposes. In addition, I suggest that there is considerable scope for a text-book which will explain clearly, in the simplest possible terms, just what is implied when it is said that energy "represents" matter and that matter "represents" mass, while mass is the name given to inertia when expressed as a measurable quantity. Without some such explanation, the youth who has accepted the statement, made without qualification, that mass is the quantity of matter in a body, is likely to have considerable difficulty in adjusting himself to modern views on the subject.

Yours faithfully,
HUGH P. VOWLES.

The Leaze,
Oxlynch, Stonehouse, Glos.
August 25, 1947.

SHEAR STRESSES IN SPRINGS.

TO THE EDITOR OF ENGINEERING.

SIR,—I should be obliged if you could find space in your esteemed journal to bring the following information to the notice of your readers, particularly to those who may be interested in helical springs, from either a theoretical or practical viewpoint.

I have calculated the values of the products $C_1 \times C_R$ and $C'_1 \times C'_R$ involved in the writer's formula for the shear stresses at the inner and outer extremities of the bar (or wires) of a helical spring. The Adams formula states that:—

Maximum shear stress at inside of coils = Q = $C_1 \times C_R \times f_s$ . . . . . (1)

Maximum shear stress at outside of coils = Q′ = $C'_1 \times C'_R \times f_s$ . . . . . (1a)

where f_s is the corresponding stress in a straight bar under the same torque. Clearly

$$f_s = \frac{8cW}{\pi d^2}, \text{ where } c = \frac{D}{d} = \text{spring "index"}. \quad (2)$$

The coefficients $C_1 \times C_R$ and $C'_1 \times C'_R$ are complex functions of c, and are given by:—

$$C_1 \times C_R = \frac{1}{4(c-1)\sqrt{4c^2+1}} \sqrt{\left[2{\cdot}5578\left(c+\sqrt{c^2-1}\right)+\frac{1}{c}-2{\cdot}2789\right]^2 + \left[\frac{11{\cdot}934\left(2-c+\sqrt{c^2-1}\right)}{9-4c^2+\left(4c-\frac{7}{c}\right)\sqrt{c^2-1}} + 5\tfrac{1}{2}(c-1)\right]^2} \quad . \quad . \quad . \quad . \quad (3)$$

$$C'_1 \times C'_R = \frac{1}{4(c+1)\sqrt{4c^2+1}} \sqrt{\left[2{\cdot}5578\left(c+\sqrt{c^2-1}\right)-\frac{1}{c}+0{\cdot}2789\right]^2 + \left[\frac{11{\cdot}934\left(2+c-\sqrt{c^2-1}\right)}{9-4c^2+\left(4c-\frac{7}{c}\right)\sqrt{c^2-1}} - 5\tfrac{1}{2}(c+1)\right]^2} \quad . \quad . \quad . \quad . \quad (4)$$

In addition, I have derived the following rational formula for the "proof" stress, or the stress to be used when designing the spring in accordance with equation (1) above. The new formula for stress is:—

$$Q = \frac{C_1 \times C_R}{C'_1 \times C'_R} \times q_i \left\{1 + 0{\cdot}01316875\,(c-4)\right\} \quad (5)$$

in which q_i is the initial proportional limit stress (in torsion) of the material, with no overstrain. It will thus be seen that the design stress is a simple function of the spring index, since the values of $C_1 \times C_R$ and $C'_1 \times C'_R$ are known.

Finally, if we combine equations (1) and (5) we have, for the axial "solid" load, W, in a compression spring:

$$W = \frac{\pi d^3 Q}{8c\,(C_1 \times C_R)} = \frac{\pi d^3 q_i}{8c}\left[\frac{1+0{\cdot}01316875\,(c-4)}{C'_1 \times C'_R}\right]. \quad . \quad . \quad . \quad . \quad (6)$$

The writer, from his own tests, has found

q_i = 34 tons per sq. in., for a good 1 per cent. carbon steel;
= 28 tons per sq. in., for a silico-manganese steel;
= 42·5 tons per sq. in., for a chromium-vanadium steel.

Each of these steels was oil-quenched from 850 deg. C. and tempered at 470 deg. C.

The calculated values required for use in equations (1), (1a), (5) and (6) are tabulated below. The results will greatly simplify the work of those engineers who may have to deal with helical springs.

$c = \frac{D}{d}$	$C_1 \times C_R$	$C'_1 \times C'_R$	$\frac{Q}{q_i}$
3	1·5554	0·58074	—
4	1·3939	0·67480	2·0657
6	1·2490	0·77458	1·6550
8	1·1815	0·82689	1·5041
10	1·1423	0·85905	1·4348
12	1·11685	0·88095	1·4013
16	1·0877	0·90865	1·3862
20	1·0707	0·92593	1·4000

It will be found that the design stress, in the case of a 1 per cent. carbon steel, increases from 47·1 tons per square inch, when $c = 16$, to 56·3 tons per square inch when $c = 6$. This is in keeping with good spring practice and corresponds to an extent of overstrain at the inside of the coils of from 38·6 per cent., when $c = 16$, to 65·5 per cent. when $c = 6$.

In all the formulæ quoted above, the spring index is $c = \frac{D}{d}$.

I am, Sir,
Yours faithfully,
L. E. ADAMS, B.Sc. (Eng.) Lond.,
(Carnegie Scholar).

11, Milner-road,
Kingston-on-Thames, Surrey.
August 9, 1947.

THE NORWICH HEAT PUMP.

TO THE EDITOR OF ENGINEERING.

SIR,—The relationship between Bell and Coleman referred to in letters in your issue of September 5, page 234, and previously, and also Lord Kelvin, appears to be very succinctly given in a paper on the "Evolution of Machine and Plant Design," by Bernard C. Oldham, read before the Institute of Refrigeration on December 17, 1946, some weeks earlier than Mr. Sumner's paper to the Institution of Mechanical Engineers. Mr. Oldham's paper states that "air-compression refrigerating machines figure prominently in patents granted in 1871 to 1877, notably those communicated from Giffard, and by Bell and Coleman. Coleman (1838-1888) was chemist at the Bathgate paraffin works where the early Harrison-Siebe and Kirk machines had been installed, and Mr. Bell's company were importers of meat. Sir William Thomson, later Lord Kelvin, brought them together, and there is no doubt that Coleman's scientific training led to the rapid and continued success of their cold-air machine." As with innumerable other developments for the benefit of mankind, this was an example of collaboration between the works scientist or engineer, an industrialist with a need to be filled and finance to back it, and the academician.

Yours faithfully,
W. J. CHAMBERS.

The Rumford Club,
9, Gunterstone Road,
West Kensington, W.14.
September 9, 1947.

EFFECT OF CENTRIFUGAL FORCE IN AXIAL-FLOW TURBINES.

TO THE EDITOR OF ENGINEERING.

SIR,—In my article, I described a blading design, with cylindrical boundaries, in which the flow is in radial equilibrium throughout, and in which there is no radial-velocity component anywhere. I believe it is pretty generally recognised that a radial-velocity component is of no advantage, and rather harmful, in axial-flow turbines. I then proceeded to show that in the known free-vortex designs such radial equilibrium, such absence of radial-velocity component, cannot exist.

Mr. Atkins in his letter of your issue of May 30, on page 458, mentions the desirability of radial equilibrium. In his letter in your issue of August 29, page 210, he admits that in free-vortex design radial equilibrium does not exist in the blades; this agrees with the conclusions indicated in my article. The absence of radial equilibrium in the blades of the so-called free-vortex design means, of course, the presence of a radial-velocity component and redistribution of the mass.

Considering, for a moment, the nozzle, the new agreed radial-velocity component will have its own influence on the radial pressure distribution, which will affect the flow beyond the nozzle outlet; moreover, the flow in the nozzle outlet is not identical with the flow in the gap between the nozzle and the blade. There is, therefore, no solid foundation for the assumption of Mr. Atkins that free-vortex flow will take place after the nozzle.

Yours faithfully,
B. POCHOBRADSKY.

Fraser & Chalmers Engineering Works,
Erith, Kent.
September 15, 1947.

ROAD VEHICLES FOR RAILWAY DELIVERIES.—The Great Western Railway is to purchase 800 motor units and 400 trailers to replace worn-out road vehicles in their fleet. A number of types, from the 10-cwt. run-about to the 25-ton tractor, will be provided.

DIESEL-ENGINE GENERATING PLANT AT MADRID.—About 25 years ago, three 1,500-h.p. Sulzer two-stroke engines, directly-coupled to 15-kV three-phase alternators, were installed in the power station of the Madrid underground railway system, primarily to act as a stand-by to water-power plant. They have, however, frequently worked for 20 hours a day for months, thus enabling the service to be maintained in the driest years.

RYE HOUSE POWER STATION.—Civil engineering work has begun on the site of the power station which the Northmet Power Company is erecting at Rye House, Hoddeson, Hertfordshire. The site, which covers about 90 acres, is bounded on the north-west by the London and North Eastern Railway and on the east by the River Lee Navigation. The initial equipment, for which a number of contracts have been let, will comprise two 32-MW turbo-alternators, two 350,000-lb. boilers, one 1,900,000-gallon cooling tower, and the necessary ancillary plant.

5,000-H.P. ELECTRIC LOCOMOTIVE.—According to the *Railway Age* for August 16, 1947, the Great Northern Railway (of the United States) have recently placed two 5,000-h.p. 11-kV 25-cycle single-phase locomotives in service on the section between Wenatchee, Washington, and Skykomish, on which the ruling gradient is 2·2 per cent. These units have a tractive force of 119,000 lb. at 15·75 m.p.h. They are of the articulated-truck type, with two main four-axle trucks and two two-axle bogies. The supply voltage is stepped down to 1,350 volts in a transformer, which is connected to two motor-generator sets. Each of these sets consists of a synchronous motor, two traction generators and two exciters. These generators, in turn, supply the traction motors. Regenerative braking is fitted.

THE FUEL ECONOMY CONFERENCE.

IN last week's issue of ENGINEERING, on page 255, *ante*, a brief reference was made to the official opening, on September 2, of the Fuel Economy Conference, held at The Hague, under the auspices of the World Power Conference. We commence below a report, necessarily much condensed, of the proceedings during the nine days for which the Conference continued; but, as a matter of possible interest and convenience, since this was the first conference to be held since 1938, it may be prefaced by a summary of the various gatherings of the kind that have been organised since the inaugural World Power Conference was held at the British Empire Exhibition at Wembley in 1924.

THE WORLD POWER CONFERENCE AND ITS SECTIONAL MEETINGS.

The main objects of the World Power Conference, as it was originated by the late Mr. D. N. Dunlop, was to provide a common meeting ground for the experts in the different branches of power and fuel technology, and for the engineers and administrators, scientists and economists, to whom must be delegated the practical problems of fuel and power utilisation in the most efficient manner, whether judged by technical or commercial standards. So far, there have been only three full conferences: the first in London in 1924, as stated, and the second and third, respectively, in Berlin in 1930 and Washington, D.C., in 1936. The principal purpose of the 1924 Conference was to make an inventory of world resources of fuel and power. The second Conference may be described as a continuation of the first, with very general terms of reference, but the third attempted to be a little more specific, the subject being "National Power Economy."

It was soon appreciated that so large a gathering as a full conference—the membership at Berlin in 1930 was not far short of 4,000, and nearly 3,000, from 54 countries, went to Washington in 1936—should not and could not meet at very frequent intervals; but that there were many related matters which might be discussed during the intervening periods. Accordingly, the practice was adopted of holding sectional conferences, of more manageable proportions. In pursuance of this policy, sectional meetings have been held at Basle, in 1926, on water-power development and inland navigation; in London (1928) on fuel economics and utilisation; at Barcelona (1929) on water resources; at Tokyo, in the same year, with a general programme, having a leaning towards electrical power; in Stockholm (1933) on large-scale industrial power problems, and transport; on chemical engineering, in London, in 1936; and at Vienna (1938) on agricultural, domestic, and various small-scale fields for the use of power. Concurrently with the 1933 meeting, there was held the first Congress on Large Dams, and a second was held at Washington in 1936. There is to be a third in 1948, at Stockholm.

Each conference, main or sectional, is organised under various subject headings, and the papers contributed in each group or division are circulated in advance to the participants. They are not read or presented by the authors in person, but are reviewed by *rapporteurs*; a procedure which is virtually enforced by the number of the papers and the language difficulties inseparable from gatherings of international scope. The summaries which follow, in the case of the Fuel Economy Conference at The Hague, are based upon these reviews. Unfortunately, it is not practicable to report the subsequent discussions, although many of these contained comments of considerable value; but a full report will be available in due course in the published *Transactions*, as in the case of previous Conferences.

FUEL ECONOMY SINCE 1939.

The first technical session was held in the afternoon of September 2, when Dr. W. Lulofs presented a masterly condensation of 19 papers dealing, from the standpoint of the member countries represented at the Conference, with the subject of "Fuel Economy Since 1939." The British contributions to this symposium, which were published from the Central Office of the World Power Conference some six months ago, were reviewed on page 338 of our issue of April 25.

There was a sharp and obvious distinction, said Dr. Lulofs, between the situation in the countries overrun by Germany and those of the Allies. The people of the invaded countries had no inducement but compulsion to reduce fuel consumption; that compulsion was severe and caused great hardships, but few technical and economic data of any value could be derived in consequence of it. Other countries, whether in the war, or not, which depended largely on coal, suffered because the labour was not available to ensure their customary supplies and some were forced to use extreme measures to meet the shortage; Argentina, for example, burned 3,000,000 tons of grain as fuel, at a time when, in other parts of the world, there was a lack of food amounting to actual starvation. Coal was still the principal source of energy and there was likely to be a shortage of it practically all over the world for many years to come.

The changes in the availability of coal, Dr. Lulofs continued, might be illustrated by a few typical figures. In Great Britain, the output had declined steadily since 1938, the total falling from 227 million short tons in that year to 175·5 millions in 1945. For France, the corresponding figures were 50 and 35 million tons, respectively, but the use of 40,000 German prisoners in the mines had produced a slight increase since then. Only in Germany was a steady rise recorded, from 199 million short tons in 1939 to 269 million in 1943, due to the employment of forced foreign labour; but the output per man fell from 1·38 tons per shift to 1·17 tons. The tendency was still for outputs to decline, and for the quality of the coal to deteriorate. Before the war, France imported annually 20 million tons of coal. The French production per man-shift dropped from 0·883 ton in 1938 to 0·615 ton in 1947. The quality was poor, and only about 57 per cent. of the output was marketable. In the United States, production difficulties had practically disappeared, except for labour disputes. Austria produced about 3½ million tons annually and imported about the same amount. In Holland, the pre-war production was between 12 and 13 million tons, but output per man-shift had since fallen from 1·645 tons to 0·99 ton.

Of the countries mainly dependent on imported coal, Sweden took 8·2 million tons of coal and coke before the war, but in 1944 only 3·5 millions, and in 1945, a mere 400,000 tons. In 1946, the import rose again to 3·6 million tons, though hydro-electric power was being used to a great extent. Denmark imported, before the war, 4·2 million tons of coal and 1·5 million tons of coke. Eire formerly took between 2·5 and 3 million tons, which had fallen to only 750,000 tons: figures for Argentina were closely similar. Switzerland imported 3,300,000 tons in 1938—about the same as in 1913, the increased demand for power being met by the construction of additional hydro-electric plants. In Finland, imports of coal and coke fell from 1·9 million tons in 1938 to 880,000 tons in 1946-7; but the total power consumption, expressed as equivalent coal, advanced from 3·95 million tons to 4·35 millions in that period, increased hydro-electric power and a heavier consumption of wood accounting for the difference. General experience, said Dr. Lulofs, in concluding his review of the coal position, was that intense mechanisation offered the only remedy for the decreased output per man-shift.

Turning to liquid fuels and natural gas, Dr. Lulofs noted that, during the war, Britain produced about 600,000 tons of creosote and pitch by tar distillation, and still obtained a useful supply of fuel from that source. Before the war, France produced only 70,000 to 80,000 tons of crude oil yearly, but imported about 8·5 million tons, possessing extensive refineries. In 1939, an oilfield was tapped in the south of France, and gave about 200,000 cub. m. of gas and entrained spirit daily, with the prospect of more; and, a few years later, natural gas was found and used on the border between Holland and Germany. In Australia, there were large deposits of oil shale which, however, could not be exploited because of the lack of labour. There was shale also in Sweden, where surplus hydro-electric power was used to heat it and drive off most of the oil it contained; shale was also mined. In the United States, the production of crude oil had been able to keep pace with the growing demand for energy; but it had been necessary, during the war, to rearrange much of the domestic system of pipelines and to build new lines; the refining capacity also had been greatly increased. The pre-war Danish import of oil and petrol dropped to practically nothing during the war; but natural gas had been found in the north of Jutland and was used as fuel for motor cars. Switzerland's supplies of imported oil stopped in June, 1940, but hydro-electric sources of power were used to meet the deficiency. Czechoslovakia met the demand for fuel by exploiting more fully the lignite deposits of Northern Bohemia. Gas producers had been used for motor vehicles throughout Western Europe during the war, and for the Diesel-driven pumping plants which drained the Dutch polders. In general, Dr. Lulofs doubted whether the increases in oil and natural gas supplies could compensate for the falling coal production.

Before the war, brown coal was regarded as a fuel of inferior quality, but the deterioration in coal had been such that it could not be so considered any longer: it provided about half of the German electricity production in coal-fired power stations, and could be used also to produce gas of good quality. It was more correct to apply the term "inferior" to unscreened slack, duff, coke breeze, slurries, etc. In France, combustion efficiencies as high as 80 per cent. were claimed with breeze, lignite, peat, and sawdust; it was stated that 3,000,000 tons of marketable coal had been saved by these means. Sweden had made extensive and successful use of peat, the consumption rising from a pre-war figure of only 30,000 tons a year to 1,200,000 tons. Peat was used in gas production. Wood had been used extensively to produce charcoal, especially for metallurgical purposes, but its use as a raw fuel would be reduced considerably as soon as better supplies of coal became available. Charcoal production had been increased greatly in the Argentine, and the railways had used as much as 4,000,000 tons of wood yearly as fuel. In Ireland, peat briquettes had been made, using 8 to 10 per cent. of pitch as a binder, and with it a small quantity of coal. In Germany, coal containing up to 45 per cent. of ash had been burned on compartment stokers.

The concluding part of Dr. Lulofs' summary dealt with hydro-electric developments and high-tension transmission lines, particulars of which are generally well known. He suggested that special attention should be given to any means likely to increase coal output per man-shift; to the possibility of developing further the production of oil and natural gas; to the question whether, in spite of their success in using poor coals under war-time conditions, it was advisable to ask consumers to continue the use of such coals; and, in view of the seasonal character of hydro-electric power generation, and the shortage of thermal power stations, to the development of other sources of supply, such as tidal power plants and wind power.

(To be continued.)

STUDY-TOUR OF SWISS RAILWAY METHODS.—Twelve London Transport employees left for Switzerland on Monday, September 15, to study methods on the most important railways in that country. Visits will also be paid to hydro-electric plants, locomotive works and repair shops. On their return, they will write papers on what they have seen and its possible application to London transport.

ACCIDENT TO TUDOR II AIRCRAFT.—The Ministry of Supply announces that the Accidents Investigation Branch of the Ministry of Civil Aviation have found that the accident, which occurred on the Tudor II aircraft G-AGSU at Woodford Aerodrome on Saturday, August 23, was due to the fact that the aileron controls had been reversed. The behaviour of the aircraft during its final flight was consistent with this condition. The circumstances are being further investigated, but we understand that steps are being taken to alter the design so that assembly with reversed connections will be mechanically impossible.

FLYING DISPLAY OF BRITISH AIRCRAFT.

As briefly recorded on page 255, *ante*, the Eighth Flying Display and Static Exhibition, organised by the Society of British Aircraft Constructors, was held at the Radlett Aerodrome of Messrs. Handley Page, Limited, on Tuesday, Wednesday, Thursday and Friday of last week. The Society held the first exhibition of this kind in 1932, when, for the first time, the aircraft industry of this, or of any other, nation combined to stage an exhibition with flying demonstrations on the same airfield. This was the second time that the exhibition was held at Radlett, and, in the main, it followed the pattern of previous exhibitions. This year, however, the exhibition was open for four days, compared with two days last year, and during the afternoon of the first two days both military and civil aircraft were demonstrated. On the third day, the demonstrations were confined to civil aircraft and gliders, while on the fourth day all the aircraft remained on the ground so as to give the technicians of the aircraft industries of the world ample time to carry out an examination. More than 70 aircraft were on view, ranging from the largest four-engined transports and air liners to small training machines and gliders, and during the first two days, 43 of them were demonstrated in the air.

Perhaps the outstanding feature of the exhibition was the number of new aircraft on show. Since last year's display, 27 new aircraft have been developed by the British aircraft industry, nearly all of which were flown at the exhibition. All these aircraft, however, are fitted with reciprocating engines, and no new aircraft fitted with jet engines were either on view or demonstrated, the Saunders-Roe new single-seat jet-propelled flying-boat fighter, the SR/A1, failing to put in an appearance. This field, therefore, was left to the four machines which flew during last year's display, namely, the Gloster Meteor, the de Havilland D.H.108, the de Havilland Vampire, and the Vickers-Armstrongs Attacker, originally the 10/44, all of which have been described from time to time in ENGINEERING. Nevertheless, these four aircraft put up a creditable performance, all of them, particularly the Attacker, showing a remarkable turn of speed.

It must not be assumed, however, that because of the lack of new jet machines at the exhibition, little or no work is being carried out on their development. This is far from the case, as it is known that both Messrs. Gloster Aircraft Company, Limited, and Messrs. Hawker Aircraft, Limited, are actively engaged in the production of new jet-propelled fighter aircraft. In addition, this field is being examined by several firms with regard to their use in civil aviation and in this connection one of the machines flown at the demonstration, an Avro-Lancastrian fitted with two Rolls-Royce Merlin engines inboard and two de Havilland Ghost turbo-jet engines outboard, is of particular interest. The aircraft is illustrated in Fig. 1, on this page, in which the machine is shown flying on the jet engines alone, the airscrews being feathered. The Ghost-Lancastrian can be described as a flying test bed for the development of the Ghost engine, which has been selected as the power plant for the projected D.H.106, a pure-jet transport machine which is being developed by Messrs. de Havilland for use on the North Atlantic and other trunk routes. The Lancastrian is being used primarily for endurance and fuel-consumption tests, while data on high-altitude and high-speed aspects of engine performance will be provided by a Vampire fighter in which a Ghost engine has been installed.

Another aircraft which may be considered as a flying test bed is the Hermes II, manufactured by Messrs. Handley Page Limited, and flown during the display. The Hermes II is illustrated in Fig. 2, on this page, and it has been built in order to facilitate routine tests on such matters as pressurisation, air-conditioning, etc. Basically, it is similar to the Hermes IV, which is being developed for the British Overseas Airways Corporation for use on the Empire routes, but unlike the Mark IV, the Mark II is not equipped with a nose wheel, while certain other features, such as the engines and interior layout, are different. Another aircraft displayed by Messrs. Handley Page, Limited, was the Hastings four-engined military transport. This machine is shown in flight in Fig. 3, opposite, and will shortly go into service with the Royal Air Force, deliveries having commenced. It is powered with four Bristol Hercules engines, which give a maximum speed of 354 miles an hour, a cruising speed of 303 miles an hour, and a service ceiling of nearly 27,000 ft. It has a span of 113 ft. and a wing area of 1,408 sq. ft., while the overall length is 81 ft. 8 in. It has been designed to facilitate the loading of military stores, such as 25-pounder guns and 3-ton lorries, and for this reason it is constructed with a large freight door and provided with an air-transportable ramp, the total weight that may be carried being 7½ tons. When used as a troop carrier, 50 fully-equipped troops can be carried, while the ambulance version can accommodate 32 stretcher cases, 24 sitting cases, four medical attendants, and a ton of medical supplies.

Possibly the most interesting of the larger types of civil air liner displayed was the Airspeed Ambassador. The machine flown at the display is the only one of its type to have been built so far, having been completed quite recently, and, in the circumstances, its performance at the show was very creditable, the low-speed handling properties being particularly noticeable. It has been designed to meet the demand for an aircraft capable of carrying up to 48 passengers over short and medium stages of transcontinental routes, and was constructed to the order of the British Government. The machine is illustrated in Fig. 4, opposite, from which it can be seen that it is a high-wing, twin-engined aircraft of exceptionally clean form. It is of all-metal construction with a usable length of cabin exceeding 48 ft. which can be arranged, for example, to give seating accommodation for 40 passengers and leave sufficient space for two lavatories, a galley and room for baggage. Alternative interior arrangements provide accommodation for either 28, 36 or 48 passengers with similar general facilities. Basically, the fuselage of the Ambassador is of circular cross section and the entire length of the fuselage, including the crew's and rear luggage compartments, is pressurised. The interior is unobstructed from the bulkhead aft of the crew's compartment to the rear pressure bulkhead, and, in its standard form, the crew's compartment will accommodate two pilots with full dual control and a radio operator. The aircraft has a span of 115 ft. and a wing area of 1,200 sq. ft., the wing loading being 39·2 lb. per square foot at an all-up weight of 47,000 lb. The overall length is 80 ft. 3 in., while the overall height over the rudder, the highest point of the machine, is 18 ft. 10 in. It is powered by two Bristol Centauras 631 engines, each giving 2,600 brake horse-power for take-off. The engines, however, are being developed to give a considerably higher take-off power and the structure of the machine has been designed to allow the maximum weight to be increased to more than 50,000 lb. when this higher power is available. It has a cruising-speed range of 180 m.p.h. to 270 m.p.h., and since it has been designed for fast cruising at low outputs, there is a good reserve for emergencies. For instance, with one engine out of operation, its fully-loaded rate of climb, with undercarriage down and propeller windmilling, is 190 ft. a minute, and with the undercarriage retracted and propeller feathered, this figure rises to 525 ft. a minute. These figures apply to the machine when flying at 47,000 lb. and without using the higher take-off power. The payload capacity of the 40-passenger pressurised version is 8,400 lb. for an ultimate range of 1,000 statute miles when cruising at 255 m.p.h. at 12,500 ft. By substituting fuel for payload, however, the range can be increased to 2,200 miles with a payload of 5,600 lb., equivalent to the weight of 24 passengers, each with 65 lb. of baggage.

The main fuel tanks are built integrally with the wing, being situated at the root ends of the outer extensions and each tank has a capacity of 500 gallons; in addition, two auxiliary bag-type tanks, each of 300 gallons capacity, may be installed in the centre section. A thermal anti-icing system is built into the machine, three combustion heaters supplying hot air to the leading edges of the wings, the tailplane and the fin surfaces. A tricycle undercarriage of the duplex-wheel type is fitted and this is retracted hydraulically, the power being supplied from a hydraulic accumulator charged continuously by an electrically-driven pump. The nosewheel is steerable, the power for this purpose, together with that for operating the brakes and flaps, being supplied by the hydraulic system.

Several aircraft of what can best be termed the feeder-line class were on show, some of which took part in the flying display. Included among these were the Dove, manufactured by Messrs. de Havilland Aircraft Company Limited, the Concordia, manufactured by Messrs. Cunliffe-Owen Aircraft Limited, Southampton, and the Merganser, which is manufactured by the Percival Aircraft Limited, Luton.

An illustrated description of the de Havilland Dove was given in ENGINEERING, vol. 162, page 162 (1946), so that it is unnecessary to describe it here. The Cunliffe-Owen Concordia, however, is a new machine, the first flights having taken place comparatively recently. It is illustrated in Fig. 5, opposite, from which it will be seen that it is a low-wing twin-engined monoplane with a tricycle undercarriage. The machine has been designed for use on feeder lines and can carry ten passengers, together with their baggage, over distances of up to 1,000 miles. The span is 56 ft. 8 in., and the overall length 44 ft. 10 in., while the overall height over the tail, the highest point, is 16 ft. 8 in. The fuselage consists of a shell of light-alloy sheet, reinforced by extruded light-alloy bulb-angle stringers and by transverse frames and bulkheads. The stringers are continuous along the length of the fuselage, except, of course, in way of the windows and door, and the

FLYING DISPLAY AT RADLETT.

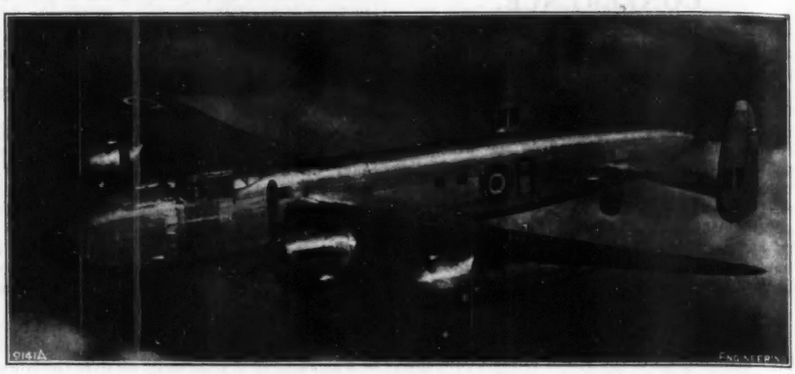

FIG. 1. AVRO "LANCASTRIAN" WITH "MERLIN" AND "GHOST" ENGINES.

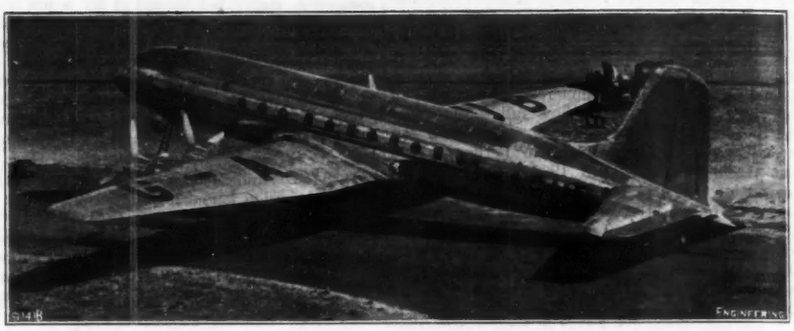

FIG. 2. "HERMES II" RESEARCH AIR LINER; MESSRS. HANDLEY PAGE LIMITED.

FLYING DISPLAY AT RADLETT.

FIG. 3. "HASTINGS MK. I" MILITARY TRANSPORT; MESSRS. HANDLEY PAGE LIMITED.

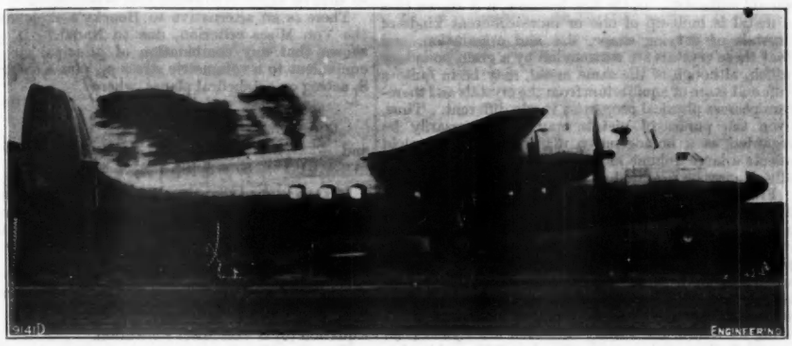

FIG. 4. "AMBASSADOR" 48-SEATER AIR LINER; MESSRS. AIRSPEED LIMITED.

FIG. 5. "CONCORDIA" FEEDER-LINE AIRCRAFT; MESSRS. CUNLIFFE-OWEN AIRCRAFT LIMITED.

lower portions of the frames serve as transverse floor-support members. A structural bulkhead separates the cockpit from the main cabin, and further structural bulkheads are provided in the nose, at the two wing pick-up points, at the fin and tailplane pick-up points, and aft of the entrance door. The wings are metal-covered and embody a single cantilever main spar, which is situated at 30 per cent. of the chord from the leading edge. The main spar is built up from light-alloy T-section extrusions, which are riveted to a plate to form an I-beam, and in plan the spar follows a straight-line between the wing tips. Ribs are fitted forward and aft of the spar, and the ends of the ribs adjacent the trailing edge of the wing are riveted to a false spar of the stiffened-web type. The light-alloy metal skin is carried round the leading edge and is riveted to the spars, ribs and angle stiffeners intercostal between the ribs. Fuel is carried in Marflex bag-type crashproof units, which are fitted into the outer and centre sections of the wing.

The Concordia is powered with two Alvis Leonides engines, each of which develops 550 h.p. at take-off. With both engines in action, the machine has a rate of climb of 1,310 ft. a minute and even with one engine stationary, the rate of climb is 217 ft. a minute. The standard aircraft is fitted with constant-speed fully-feathering airscrews which are designed so that, if required, they can be modified to incorporate pitch reversal. The single-strut Lockheed undercarriage legs are actuated electrically, and the two main wheels of the undercarriage are fitted with single disc-type hydraulic brakes. Full dual-control is fitted as standard, and the co-pilot's seat and flying controls can be removed easily. De-icing of the T.K.S. porous-strip type is provided for the leading edges of the outer wing, the fin and tail-plane leading edges, the airscrews and the pilot's windscreens.

The all-up weight of the Concordia is 12,500 lb., and the maximum useful load that can be carried is 2,100 lb. The range with this load, at sea level and a speed of 140 miles an hour, is 645 miles, while with the same load, but at a speed of 181 miles an hour and a height of 7,000 ft., the range is 575 miles. The maximum speed at an all-up weight of 12,500 lb. is 216 miles an hour at 3,000 ft., while the maximum continuous cruising speed at a mean weight of 12,000 lb. is 201 miles an hour at 10,000 ft. The most economical cruising speed is 137 miles an hour at 7,000 ft. and the recommended cruising speed 160 miles an hour at 7,000 ft. The service ceiling is 24,000 ft. and the recommended economic altitude 7,000 ft. The aircraft is available as a 10-seater or a 14-seater passenger carrier, as an ambulance, and as a freight carrier.

(To be continued.)

LABOUR NOTES.

WRITING before the Trades Union Congress at Southport had concluded its deliberations, the Editor of the Amalgamated Engineering Union's *Journal* discusses the question of making joint production committees legally obligatory throughout the engineering industry. The Congress, it will be recalled, remitted Mr. Tanner's resolution on the subject to the General Council for full examination, and presumably, the matter will come up again a year hence. "We are quite certain," the Editor says, "that unions will not undertake to deal with voluntary absenteeism, to impose penalties on their members, to consent to the extension of working hours and the dropping of restrictive practices adopted in the past for the protection of their members against employers' exploitation, unless the unions have the means, through joint production committees and the consultative and advisory machinery, of influencing the conduct of industry, and, through their voluntary system of collective bargaining, improving the workers' wages and conditions of employment."

Returns received at the head office indicate that, at the end of August, the membership of the Amalgamated Engineering Union was 809,185—an increase of 3,339 compared with the position at the end of July. During August, sick benefit was paid to 4,479 members—an increase of 44—and 19,569 members received superannuation payments—an increase of 120. Unemployment benefit was paid by the union to 1,312 members—an increase of 25—and the total number of unemployed was 3,632—a decrease of 263.

In the latest *Monthly Trade Report* of the United Patternmakers' Association, Mr. Beard, the general secretary, discusses the problems of management. The statement of Sir Stafford Cripps on the subject, "no doubt," he says, "created some feeling and resentment; indeed, the criticism of some of our members in branches and Trades Councils has been particularly forthright. This is, to some extent, understandable, for our records show that many of our members are holding down positions of some importance in industry; in fact only this month we had a request from one firm for patternmakers to replace some whom the firm desired to transfer to supervisory grades in view of their previous success in this regard. It should not be forgotten, however, that while it is true that the training of the patternmaker does produce a considerable number of men who are qualified intellectually and temperamentally for managerial posts, it is not generally true of working class society, although all trades produce a percentage, usually according to skill and training."

In Mr. Beard's opinion, management is to-day a science, and calls for training, leadership and foresight. "There is," he writes, "no mystery about it. It is the application of scientific methods to the problems of industry. It calls for specialist, technical, and administrative knowledge, and it must have concern with industrial psychology. The old conception of management, which carried with it the power to make arbitrary decisions with such power resting in the threat to dismiss while men were waiting at the gate for a job, has gone, although one still hears the statement bandied about that industry will not recover its production until there is competition among workers for the jobs available. Means will have to be found to provide for consultation and collaboration between management and men on any question in which either, or both, are interested."

"During the war," Mr. Beard continues, "machinery for joint consultation was in operation in most factories with excellent results to both sides of the industry. Since the war many factories have abandoned this machinery, apparently in the hope that they may be able to assume what they previously claimed as managerial functions. The engineering employers should realise that the spirit of 1922 is dead, when they were able to impose these conditions following the lock-out of that year. Production must now go hand in hand with consultation, for clearly there is another investment in the industry besides that of shareholders—namely, a life-times' engineering experience."

Sixty-four members were admitted in July by the United Patternmakers' Association making the total membership 15,251. There are 837 superannuated members.

A statement on the man-power situation issued last week by the Ministry of Labour and National Service indicated that the number of women included in a total working population of 20,153,000 at the end of July showed an overall decrease of 12,000, and that the number of men increased by 7,000, compared with

June, so reducing the net decrease to 5,000. The total working population at the end of July was greater than that at mid-1939 by 403,000—men 236,000 fewer, women 639,000 more—but showed a reduction since June, 1945, of approximately 1,496,000—men 461,000, women 1,035,000.

The total number of insured persons registered as unemployed was estimated at 252,000 at the end of July, compared with 260,000 in June. In mid-1939, the number was 1,270,000. The number in the Forces, auxiliary services, N.F.S., police and civilian employment decreased by 2,000, and was 1,765,000 fewer than at the end of June, 1945. The number in the Forces and auxiliary services at the end of July was 1,256,000—a decrease of 36,000 compared with June. In the 25 months from mid-1945 to the end of July there was a decrease of 3,834,000. Those employed in home civilian industries and services, and manufacture for export, increased by 1,305,000 compared with mid-1939.

In the British industries covered by the statistics regularly compiled by the Ministry of Labour and National Service, the changes in rates of wages reported to have come into operation in the United Kingdom during July resulted in an aggregate increase estimated at approximately 190,000*l.* in the weekly full-time wages of about 537,000 workpeople. In addition, a number of workpeople had their hourly rates increased so as to give approximately the same weekly wages as before for a shorter working week. The principal groups of workpeople affected by the increases in rates of wages were those employed by the main line railway companies. The changes in hours of labour reported in July resulted in an average reduction of about 3¼ hours a week for about 670,000 workpeople.

The number of industrial disputes involving stoppages of work in the United Kingdom reported to the Ministry as beginning in July was 87. In addition, 18 stoppages which began before July were still in progress at the beginning of that month. The approximate number of workpeople involved during July in these 105 stoppages, including those thrown out of work at the establishments where the stoppages occurred, though not themselves parties to the disputes, was over 52,000. The aggregate number of working days lost at the establishments concerned during July was about 167,000. Of the stoppages of work known to have been in progress at some time in July, the coal-mining industry accounted for 67, involving 12,500 workpeople and resulting in an aggregate loss of nearly 27,000 working days.

Of the 87 disputes which began in July, six directly involving 22,400 workpeople, arose out of demands for advances in wages; 34, directly involving 5,400 workpeople, out of other wage questions; seven, directly involving 600 workpeople, out of questions relating to working hours; eight, directly involving 3,200 workpeople, out of questions respecting the employment of particular classes or persons; 30, directly involving 3,300 workpeople, out of other questions relating to working arrangements; and two directly involving 100 workpeople, out of questions of trade union principle.

At a meeting in London on Wednesday last week, the executive committee of the National Union of Mineworkers adopted a plan which, it was believed, would save the principle of the five-day week agreement, and, at the same time, enable "organised overtime" to be worked throughout the industry. Under the proposed arrangement, all pits would be asked to work out for themselves how they could best put in the extra work required to increase output—whether by working longer shifts or working on Saturdays—and, having arrived at a decision, they would, in each case, be called upon to work the extra time regularly. It would be paid for at straight overtime rates, and would remain voluntary to the extent that overtime would not be insisted on to enable a man to qualify for his present bonus under the five-day week agreement.

The plan, of course, is subject to approval by the National Coal Board, which may, not unreasonably, be concerned about the probable cost. It seeks to cover the whole country, including the case of Grimethorpe, the particular trouble at which, being a matter of fact, should not take long to adjust.

The position was complicated at the week-end in South and West Yorkshire by action on the part of the Yorkshire Deputies Association, who gave notice of their intention to cease work because the overmen members were excluded from the five-day week agreement, although the deputies and shot-firers—who are also members of the Association—are included.

THE APPARENT YIELD STRENGTH OF PLAIN CARBON STEEL.*

By J. A. POPE, WH.SC., PH.D.

To say that the knowledge of the laws governing the yield of metals under the condition of compound stress is unsatisfactory is an understatement. The addition of more accurate tests, instead of clarifying the issue, adds confusion and destroys confidence in the established criteria. Different investigators have carried out experiments which have verified one criterion at the expense of the others, but, on the whole, the main criteria have about equal support. Recently, extremely accurate experiments by Morrison† have given no support to any of the criteria. In the work that follows, the present position has been analysed with special reference to yield in normalised plain carbon steel, and suggestions are made concerning size and stress-distribution effects, which bring the various test results into agreement.

It is still general among engineers and physicists to look for, and demand, a single comprehensive criterion of failure which is applicable to all metals in all conditions under any combination of stresses and for all shapes and sizes. It is surprising that this demand should still exist. In the first instance, it is known that a metal is built-up of one or more different kinds of crystals of varying shape, size and orientation, and that these crystals are surrounded by a grain boundary which, although of the same metal, may be in quite a different state of equilibrium from the crystals and therefore possess physical properties vastly different. Thus, even the purest of metals may not necessarily be regarded as a homogeneous material. Only if yield affects a large volume of metal then, perhaps statistically, it may be regarded as homogeneous.

From the mechanical standpoint metals may be divided into two main groups: (1) brittle materials and (2) ductile materials. The latter may be subdivided into two main classes: (*a*) those of which the properties change gradually from elastic to plastic conditions as the stress is increased, and (*b*) those which change suddenly from the elastic to plastic conditions as the stress is increased, the load-extension graph being horizontal for a short extension after yield (*e.g.*, annealed plain carbon steel. In class 2(*b*), yield takes place at a small portion of the material, leaving the adjacent material unaffected. As the extension continues, yield takes place at other isolated parts, the process continuing until the whole volume has yielded. At any given instant during the initial plastic yield, however, part of the metal will have yielded completely (the Lüder lines), while the remainder will be in the elastic condition. Yield is very piecemeal and not a gradual uniform process spreading through the whole volume. With class 2(*a*), however, yield is a gradual process which spreads uniformly through the whole volume of the metal. Metals 2(*a*) and 2(*b*), when subjected to mechanical deformation at low temperature so that the whole volume has yielded, are probably in a similar condition, but one which may be rather different from their conditions at the initiation of yield. Thus to group 2 may be added a third section (*c*): ductile material subjected to previous plastic deformation.

When the non-homogeneous character of even a pure metal is realised and the widely differing types and conditions of metals met with in engineering are also appreciated, to hope for one universal criterion of failure is very sanguine indeed. Even if we limit ourselves to one group of metals in one condition of heat treatment, there is no prima facie reason why a criterion for it should be possible, when it is remembered the infinitesimal quantity of metal associated with yield in bending, say, and that the elastic constants for a single grain of metal differ with its orientation. It follows then that, when examining test results, attention must be given to, and allowance made for, the nature and condition of the material used in the test, the method of stressing, and the size of the specimen. The author has limited his investigation to plain carbon steel in the annealed or normalised condition, *i.e.*, group 2(*b*). This metal, due to its sudden yield, is excellent for examining yield and, naturally, has been a favourite among investigators.

The pragmatic development of the various criteria will be omitted as it can be found in any book on the theory of elasticity, and only those three which are contending for recognition at the present day are given below.

The maximum shear stress theory maintains that the maximum shear stress only determines failure. Thus under compound stress the metal will fail when the maximum shear stress in the metal equals the shear stress induced by the tensile yield stress.

$$\therefore \text{ if } p_1 > p_2 > p_3$$
$$p_1 - p_3 = f_0 \quad . \quad . \quad . \quad (1)$$

where p_1, p_2 and p_3 are the principal stresses, and f_0 the tensile yield stress. As the result of exhaustive experiment, Guest* deduced that it would hold approximately for ductile materials but was in fact a special case of the Guest criterion given below.

The theory suggested by Von Mises as an alternative to the maximum shear stress criterion, in order to avoid the mathematical discontinuities given by the latter, may be stated as: a metal will yield under compound stress when the sum of the squares of the principal shear stresses equals half the square of the tensile yield strength.

$$\therefore \quad (p_1 - p_2)^2 + (p_2 - p_3)^2 + (p_3 - p_1)^2 = 2f_0^2 \quad (2)$$
$$\text{or} \quad S_1^2 + S_2^2 + S_3^2 = \frac{f_0^2}{2},$$

where f_0 is the yield stress in tension and S_1, S_2 and S_3 are the principal shear stresses. It was later shown by Hencky that this equation represents the condition of maximum shear strain energy. This involves the assumption that a metal yields under compound stress when the total shear-strain energy equals the shear-strain energy stored at tensile yield. This assumes that the volumetric strain energy has no effect, or that its effect is so small that it is insignificant.

There is an alternative to Hencky's explanation of the Von Mises criterion, due to Nadai.† It can be shown that any combination of principal stresses is equivalent to a volumetric stress p_m plus a shear stress S_7 acting on octahedral planes, where

$$p_m = \frac{p_1 + p_2 + p_3}{3}$$

and

$$S_7 = \tfrac{1}{3}(S_1^2 + S_2^2 + S_3^2)^{\frac{1}{2}}.$$

If it is assumed that the shear stress on the octahedral planes is the criterion, the volumetric stress having no effect, then S_7 equals a constant for a given metal.

In the case of yield in simple tension, we have

$$S_7^2 = \tfrac{2}{9}f_0^2$$
$$\therefore \quad S_1^2 + S_2^2 + S_3^2 = \frac{f_0^2}{2}. \quad . \quad . \quad (3)$$

Equation (3) is Von Mises's criterion.

Thus Von Mises's criterion may be defined as follows: a metal will yield under any combination of principal stresses when the shear stress on the octahedral plane is equal to the shear stress produced on that plane during yield in simple tension.

If yield is initiated by a shearing action we should expect yield to occur on the plane of maximum shear and not on the octahedral plane. From this point of view Nadai's interpretation of Von Mises's hypothesis does not seem very logical. The two assumptions made are: (*a*) yield occurs when a limiting shear stress on the octahedral plane is reached, and (*b*) the volumetric stress (which is the normal stress on the octahedral plane) $\frac{p_1 + p_2 + p_3}{3}$ has no effect upon the yield.

It has been suggested by Nadai that, in order to cover materials which have different yield strengths in tension and compression, and incidentally to allow for the possibility of failure by volumetric tension, Von Mise's criterion could be modified to be analogous to the Guest criterion. This would give the critical value of S_7 as a function of p_m. Then

$$\tfrac{2}{3}\sqrt{S_1^2 + S_2^2 + S_3^2} = \phi(p_m).$$

Guest‡ maintains that the volumetric stress must have an effect upon the yield strength of a material, and consequently has modified the maximum shear stress criterion as follows:—

$$p_1 - p_3 + \lambda(p_1 + p_3) = 2q_0 \quad . \quad . \quad (4)$$

where λ is given the paradoxical title "a variable constant" and q_0 is the yield stress in shear. Exactly how variable λ is, is not very clear. It seems to be a constant for the metal, but not so fundamental a constant as Young's Modulus or Poisson's Ratio which are little affected by the condition of the metal; for example, λ might be affected by grain size. It seems that this criterion was initially intended to apply to ductile materials, but Prof. Guest now feels that it is applicable to all materials which are isotropic.

Cook§ was among the first to draw attention to the effect of size of specimen upon the yield strength of a metal, and states "the surface material may possess a greater resistance to the dislocation by virtue of its being at the surface, as distinct from any mechanical or heat treatment it may receive." Morrison points out that yield cannot occur in an individual crystal sur-

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* Paper read before Section G of the British Association, at Dundee on Tuesday, September 2, 1947. Abridged.

† J. L. M. Morrison, *Proc. Inst. Mech.E.*, vol. 142, page 193 (1939).

* J. J. Guest. *Phil. Mag.*, July, 1900.

† A. Nadai. *Trans. A.S.M.E.*, vol. 55, page 111 (1933).

‡ J. J. Guest. ENGINEERING, vol. 150, page 261 (1940).

§ G. Cook. *Phil. Trans. Roy. Soc. Series* A, vol. 230, page 103 (1932).

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Fig. 1.

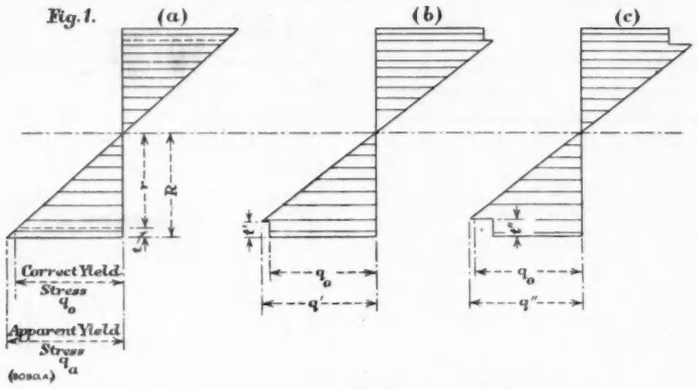


Fig. 2.

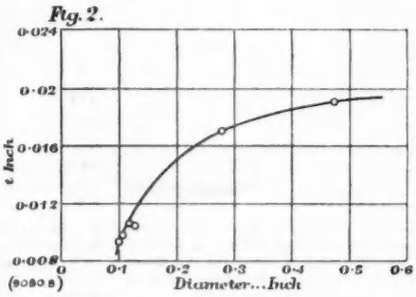


Fig. 4.

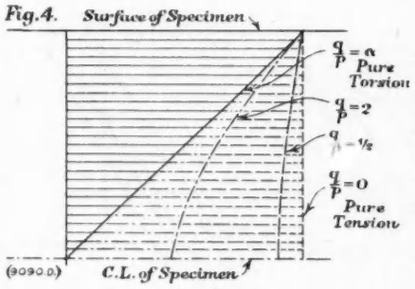
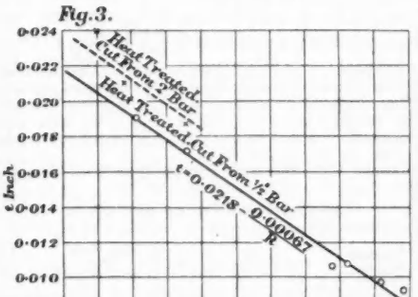


Fig. 3.



rounded by unyielding material but only in a number of crystals which occupy sufficient volume to allow for the readjustment. Therefore, yield due to non-uniformly distributed stress cannot occur until the stress, some distance below the surface of the specimen, has reached the critical value. This seems to the author to be perfectly sound reasoning, and the high values obtained for the yield stress in torsion can probably be explained by this simple mechanical process. Morrison, however, when accounting for the size effect in torsion, assumed that the thickness of the lamination t was a constant for the material and independent of the specimen size. It has been indicated already by Cook that it depends upon both the type of stress and the size of specimen, and there seems little reason to doubt that t depends upon these variables.

It follows, then, that in all tests having non-uniform distribution of stress, two variables are present: (1) the criterion governing failure, and (2) size and stress-distribution effect. To analyse test results the law governing one must be assumed and then the variation of the other deduced from the test results. In the past, with few exceptions, the size effect has been ignored, and the test results taken as a direct indication of the laws governing failure. This accounts for the fact that test results can be found which will give support to any of the criteria of failure. By choosing suitable size of specimens, apparent evidence to support any criterion may be obtained. The author proposes to reverse the procedure; that is, to assume the criterion of failure and from the various test results deduce the laws governing size and stress-distribution effect. It will be necessary first to survey the various criteria which have been mentioned and deduce which is more likely to apply to normalised (or annealed) plain carbon steels. Only Guest's Law is affected by the volumetric stress, and for this reason it will be examined first.

Let it be supposed that a volumetric stress V is superimposed on any given system of stress, then:

$$p_1 - p_2 + \lambda(p_1 + p_2 + 2v) = 2q_0. \quad . \quad (5)$$

Thus, from (5) failure will occur due to volumetric stress only when $V_0 = \frac{q_0}{\lambda}$. The value of V_0 from Guest's criterion can be any value in tension, depending upon the value of λ. Compressive volumetric stress, however, will not produce failure according to this criterion, since a compressive volumetric stress increases the shear strength. It seems difficult then to prove or disprove the Guest criterion by direct methods, since tests in volumetric tension are impossible.

The value of λ, however, can be calculated from the value obtained for q_a, the apparent yield stress in shear, from two tests involving different combinations of principal stresses. It is essential, however, that the calculation be based on tests in which the mode of the yield is always the same, and size effect, if present, is the same in all tests. This is the case for tension and compression tests where a relatively large volume of metal is associated with the yield. The stress is uniformly distributed and therefore no size effect is evidenced, provided that the specimens are of a reasonable size.

We may use with confidence the results of Morrison. He obtained for his steel 23·22 tons per square inch tension and 22·9 tons per square inch compression. From this we see that volumetric tension increases the yield strength slightly and a value for λ equal to $-0{\cdot}00694$ is obtained. This value is small and it seems reasonable to suggest that, in general, for mild steel, the volumetric stress has no effect and $\lambda = 0$. Thus, since λ equals 0, the Guest criterion reduces itself to the maximum shear-stress criterion, and as far as normalised mild steel is concerned, the Guest criterion need not be considered further. In passing, it may be pointed out that λ cannot be calculated from tensile and pure torsion tests, where the mode of yield is different for the two tests and a size effect is present in the torsion test.

No effort has been made to prove or disprove the Guest criterion. Direct evidence of its validity or invalidity is non-existent and seems impossible to obtain experimentally. To the author, this criterion seems a good working general hypothesis, provided that λ is calculated from the tension and compression tests only.

It has yet to be decided which of the maximum shear stress, or Von Mises's-Hencky criteria is more applicable to mild steel. Size effect in cylinders subjected to torsion has been clearly demonstrated by Morrison, who obtained values of $\frac{2q_a}{f_0}$ ranging from 1·054 to 1·218 for specimens with diameters ranging from 1·0 in. to 0·1018 in., respectively, where q_a is the apparent shear stress at yield. Now, size effect is only evidenced when the stress distribution is not uniform, and is generally considered to be due to the fact that yield cannot take place in a lamination of infinitesimal thickness, but must have a thickness of one or more crystal breadths. Thus, the observed yield stress in cylinders subjected to torsion must always be larger than that obtained by uniformly distributed stress; that is, the apparent yield strength must always be greater than that predicted by the criterion of yield.

According to the maximum shear-stress theory, the shear stress should equal $\frac{f_0}{2}\left(i.e.\ \frac{2q_0}{f_0} = 1\right)$ and, therefore, $\frac{2q_a}{f_0} > 1$ when size effect is present. It will be seen from the figures given above that $\frac{2q_a}{f_0}$ is always >1. If the maximum shear strain energy criterion is used, however, we have that, for torsion

$$\sqrt{3}q_0 = f_0, \text{ or } \frac{2q_0}{f_0} = \frac{2}{\sqrt{3}} = 1{\cdot}154 \quad \therefore \quad \frac{2q_a}{f_0}$$

should not be less than 1·154, but for 1·0-in. diameter specimens $\frac{2q_a}{f_0}$ equals 1·054, which is less by 10 per cent. than that predicted by the Von Mises's-Hencky criterion. This is much too large to be attributed to experimental error. Thus, it seems unlikely that this criterion is applicable to normalised plain carbon steel.

Apparently then the experimental results have demonstrated that for normalised plain carbon steel the only criterion which is at all reasonable is the maximum shear-stress theory. It has not been proved to be correct; it has simply been demonstrated that it is the only reasonable criterion. To prove its correctness is impossible. The only method by which the yield strength in shear can be measured is by torsion tests, but with these tests a size effect is present, and the observed yield strength is apparent and not real.

The only way to get the true yield stress in shear, by direct experiment, is to test a specimen of infinite radius, which, of course, is impossible, but if the curve of $\frac{\text{apparent shear stress}}{\text{tensile yield stress}}\left(\frac{q_a}{f_0}\right)$ plotted against diameter of specimen were produced to infinity, it is conceivable that it is asymptotic to $\frac{q_a}{f_0} = 0{\cdot}5$.

From the survey given above of the experimental evidence available, the following assumptions will be made as they seem the most reasonable, and will form the basis of all subsequent work in this paper.

(1) The criterion of failure for normalised carbon steel is the maximum shear stress theory. The true shear yield strength of a metal (q_0) is equal to half the tensile yield strength of the metal $\left(i.e.\ \frac{f_0}{2}\right)$.

(2) With non-uniformly distributed stress, yield will not occur until the maximum shear strength at some distance t below the surface of the specimen has reached a value equal to the true shear stress $\left(\frac{f_0}{2}\right)$.

(3) The variation of stress across this lamination t is proportional to the variation of strain.

(4) The value of t depends upon the condition of the metal, type of stress and size of specimen.

The process of yield in bending or torsion, based on assumptions 2 and 3, above, is shown diagrammatically in Fig. 1, on this page. Fig. 1(*a*) shows the stress distribution immediately before yield, which is the point of interest at the moment. Fig. 1(*b*) shows the stress distribution immediately yield commences where $t' > t$; $q^1 > q_0$ in order that the applied load may still be maintained. Fig. 1 (*c*) shows the final condition of a metal having an upper and lower yield $t'' > t' > t$ and $q'' > q_0$. In this case Fig. 1 (*b*) represents an intermediate stage.

Morrison assumed that t was a function of the metal only. It seems, however, that it is also a function of specimen shape and size. If the same metal is used throughout a series of tests, then t becomes a function of specimen size only. From Fig. 1 (*a*) it will be seen that it is a simple matter to calculate t for any specimen, provided that the apparent shear strength q_a and the tensile yield strength f_0 are known. Then, if R equals the radius of the specimen, $\frac{q_a}{q_0} = \frac{R}{R - t}$, but, from assumption, (1), $q_0 = \frac{f_0}{2}$.

$$\therefore \quad t = \left(1 - \frac{f_0}{2q_a}\right)R.$$

The results of Morrison are examined to see what relationship exists between specimen radius R and t. Tables I and II show the results of these calculations. Fig. 2, on this page, shows t plotted against diameter of specimen and although the points all lie well on the curve drawn, the curve is not illuminating as regards the law connecting t and D.

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Fig. 5.

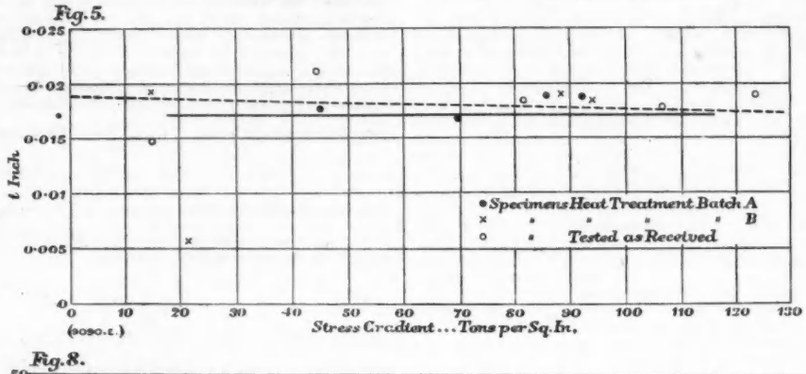


Fig. 6.

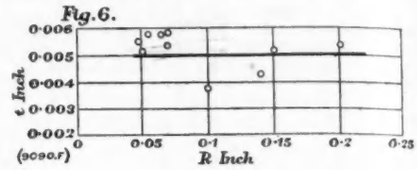


Fig. 7.

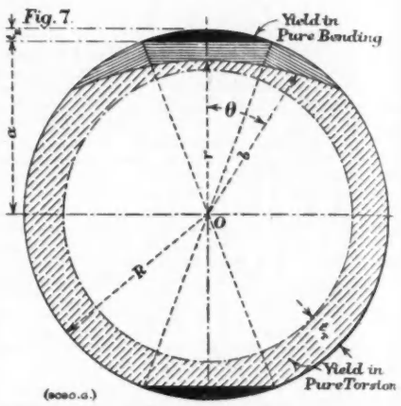
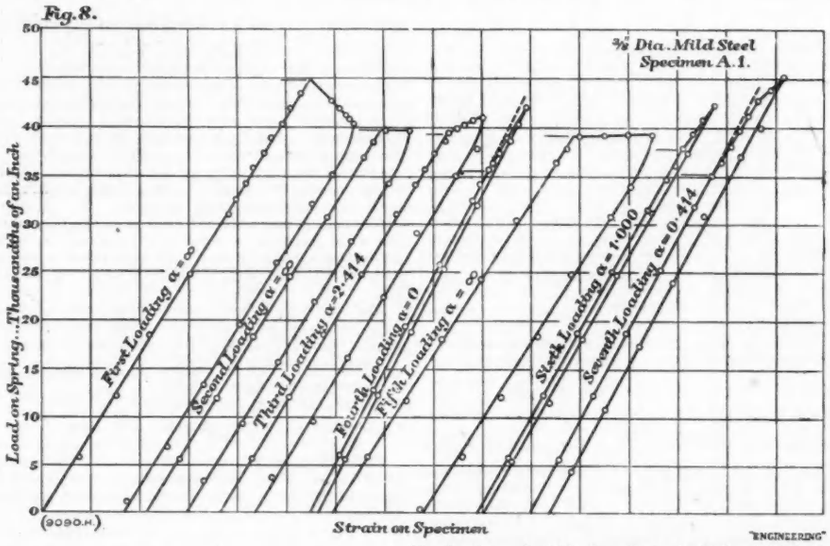


Fig. 8.



Next t was plotted against $\frac{1}{R}$, Fig. 3, page 285, and it will be noted that, for the specimen cut from ½-in. diameter bar, a good straight line is obtained. The relationship between t and R is $t = 0{\cdot}0218 - \frac{0{\cdot}00067}{R}$ in. There is some deviation from the straight line for the smaller diameter, but it is obvious that this empirical rule must have a limited range of application, since when $R < \frac{0{\cdot}00067}{0{\cdot}0218}$ $(= 0{\cdot}038)$, t would become negative, which is impossible. Within practical limits, however, the law may be taken to hold. At first sight it may be thought obvious that t would be a function of $\frac{1}{R}$ since the smaller R the greater the stress gradient across the specimen, and, therefore, for a given value of t, the greater would be the stress difference across the lamination of yield, the effect of which might be to reduce the value of t. The effect of stress gradient, as distinct from the size of the specimen, can be explored by examining the results of the combined tension and torsion tests of Morrison.

TABLE I.—*Variation of* t *with Diameter of Specimen.*

Specimens Machined from ½-in. dia. Bar, Normalised
$f_0 = 22{\cdot}7$ tons per sq. in.
R = Radius of Specimen.

Diameter of Specimen. Inch.	Apparent Shear Stress q_a. Tons per sq. in.	$t = R - r$. Inch.	$\frac{1}{R}$.
0·1018	13·83	0·0092	19·7
0·1091	13·8	0·0097	18·35
0·1215	13·8	0·01075	16·5
0·1280	13·78	0·0106	15·6
0·2782	12·96	0·0171	7·19
0·4729	12·36	0·019	4·23

TABLE II.—*Specimens Machined from* 2*-in. dia. Bar, Normalised.*

Diameter of Specimen. Inch.	$\frac{q_a}{f_0}$.	$t = R - r$. Inch.	$\frac{1}{R}$.
1	0·525	0·024	2
0·564	0·54	0·021	3·55
0·282	0·576	0·0187	7·1

Table I.—Specimens Machined from ½ in. Diameter Bars.

All stresses given in tons per sq. inch.

Specimen Number.	p.	q_a.	q_c.	Max. Shear Stress. Corrected.	$q_0 = \frac{f_0}{2}$.
6A	17·91	8·15	7·05	11·38	11·31
7A	8·96	12 16	10·52	11·43	11·31
8A	13·33	10·56	9·15	11·32	11·31
7B	4·75	12·97	11·2	11·45	11·49
8B	20·91	4·95	4·28	11·3	11·49
9B	21·32	4·95	4·28	11·5	11·49
7	18·03	13·92	12·09	15·1	15·1
8	11·64	15·92	13·8	14·98	15·1
11	27·7	6·63	5·75	15·00	15·1
12	24·15	10·68	9·25	15·2	15·1

Under combined tension and torsion and torsion, the whole circumference of the specimen arrives at the yield stress simultaneously, similar to pure torsion, except that, in this case, the stress gradient for the maximum shear stress depends not only upon the radius of the specimen but also upon the ratio of the torsional stress to the direct stress (*i.e.*, the ratio $\frac{q}{p}$). The stress distribution for various values of $\frac{q}{p}$ is shown in Fig. 4, page 285, which demonstrates clearly the effect of this ratio upon the stress gradient.

The values of t for Morrison's tests on heat-treated specimens and specimens not heat-treated have been plotted against stress gradient in Fig. 5, on this page, for specimens of 0·141-in. radius. It will be noted that, except for one bad point for a specimen in batch B, the points all lie well on a horizontal straight line (the actual horizontal line drawn is calculated from Fig. 3). Of course, as the ratio $\frac{q}{p}$ is reduced, the line of maximum shear changes from a circle at right angles to the direction of the centre line of the specimen to a spiral the angle of which increases until, in pure tension, it is a series of planes inclined at 45 deg. to the centre-line of the specimen. The change of direction of the lines of maximum shear will change the effective radius of the specimen. The effect of this should be to increase the value of t as the ratio $\frac{q}{p}$ decreases. The dotted line in Fig. 5 represents this effect, and it will be observed that its effect is very slight and, within the accuracy of the experiments, may be neglected.

It follows then that the value of t is not affected by the stress gradient and therefore the fact that in pure torsion the value of t is a function of $\frac{1}{R}$ must be due to the geometry of yield only. Another interesting point revealed by Fig. 5 is that the value of t is the same for both heat-treated and non heat-treated specimens.

Under combined tension and torsion the value of the lamination of yield may be taken as constant for all combinations of stress and equal to the value obtained for pure torsion. It is only the shear component which is affected by the lamination t. To obtain the correct value of the shear component the apparent shear components should be multiplied by $\frac{R - t_T}{R}$, where t_T is the lamination of yield for pure torsion. The maximum shear stress is then calculated by the usual method. The results of such calculations for Morrison's results are shown in Table III. From the last two columns of this table it will be noted that, when correction is made for the stress-distribution effect, the maximum shear stress deviates from $\frac{f_0}{2}$ by an average amount of only 0·7 per cent.

The actual value of f_b, the apparent yield strength in bending, is very difficult to measure, since, even with metals possessing plastic yield, such a small portion of the specimen is affected by the initial yield that on the flexure curves the breakdown of elastic conditions appears to be gradual, and the exact value of the bending moment at which yield is initiated is difficult to decided. Morrison, in his paper, wisely refrained from giving a value of $\frac{f_b}{f_0}$, at yield in his flexure tests. In some cases, however, its determination cannot be avoided. The author is indebted to Professor Morrison for giving him a print of the original drawing of Fig. 18 in his paper. From this print the values of $\frac{f_b}{f_0}$, for various specimen radii have been read off and t calculated, the results being given in Table IV, opposite. Fig. 6 shows t plotted against the radius of the specimen. There is considerable scatter and the only conclusion that can be drawn is that, within the limits of experimental evidence, t is independent of the diameter of specimen, and has a value of about 0·005 in.

Fig. 7, above, shows the ring of metal associated with yield in pure torsion, the small fibres of the specimen at which yield initiates in pure bending, the suggested lamination of yield in combined bending and

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Fig. 9.

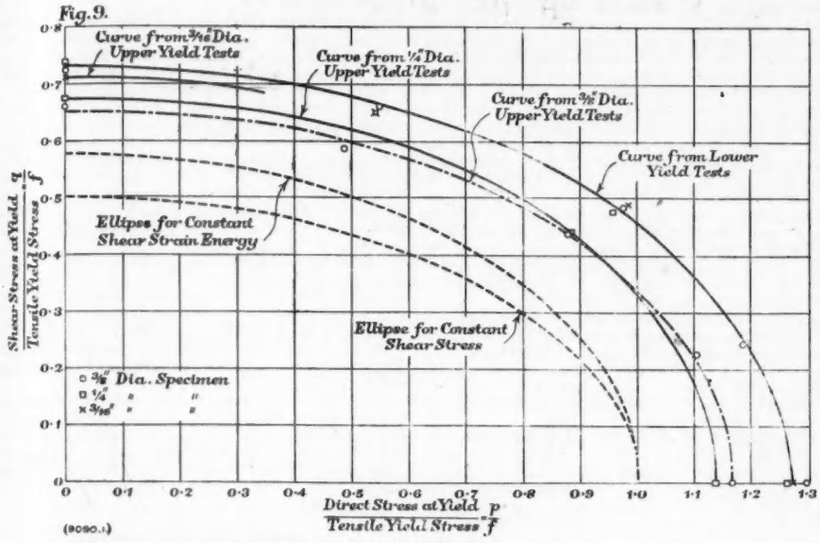

Curve from 3/16" Dia. Upper Yield Tests
Curve from 1/4" Dia. Upper Yield Tests
Curve from 3/8" Dia. Upper Yield Tests
Curve from Lower Yield Tests
Ellipse for Constant Shear Strain Energy
Ellipse for Constant Shear Stress
3/8" Dia. Specimen
1/4" " "
3/16" " "
Shear Stress at Yield / Tensile Yield Stress = q/f
Direct Stress at Yield / Tensile Yield Stress = p/f
(SOSO.I.)

Fig. 10.

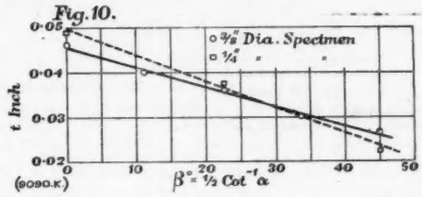
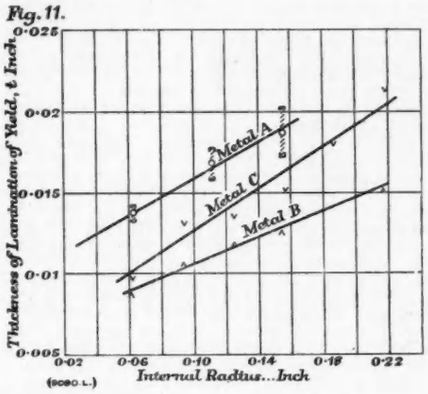


Fig. 11.



twisting, and the various symbols used. In this case, the distribution of direct stress and shear is proportional to the distance from the neutral axis; thus the maximum shear stress also will be proportional to the distance from the neutral axis,

TABLE IV.

Radius R of Specimen in Inches.	$\frac{f_0}{f_b}$.	t. Inch.
0·2001	0·973	0·0054
0·1501	0·995	0·0054
0·1390	0·969	0·0043
0·0995	0·962	0·00378
0·07	0·922	0·00545
0·0705	0·917	0·00585
0·0645	0·91	0·0058
0·0576	0·899	0·00584
0·0501	0·899	0·00515
0·0482	0·886	0·0055

$$\therefore q_0 = \frac{r}{R}\sqrt{\left(\frac{p}{2}\right)^2 + q^2} = \frac{r}{R}\frac{p}{2}\sqrt{1+\alpha^2} \quad . \quad (6)$$

where $\alpha = \frac{2q}{p}$; q = apparent maximum shear stress due to torsion; p = apparent maximum direct stress due to bending, and r is a function of α.

Also

$$q_0 = \sqrt{\left(\frac{p}{2}\right)^2 \frac{b^2}{R^2}\cos^2\theta + \left(\frac{b}{R}\right)^2 q^2}$$

$$= \frac{b}{R}\frac{p}{2}\sqrt{\cos\theta - \alpha^2}. \quad . \quad . \quad (7)$$

Equating (6) and (7)

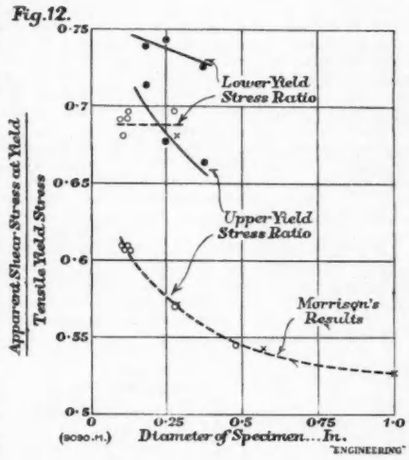
$$b = r\sqrt{\frac{1+\alpha^2}{\cos^2\theta + \alpha^2}} \quad . \quad . \quad (8)$$

The locus of the end of b gives us the lower boundary of the metal which takes part in yield. When $q = 0$ (*i.e.*, pure bending) $\alpha = 0$; $b = \frac{r}{\cos\theta}$. Thus θ is half the angle subtended at the centre of the specimen by the portion which yields during pure bending. In pure torsion, when $p = 0$, $\alpha = \infty$, then $b = r$, *i.e.*, a circumferential ring of metal yields equal to $(R - r)$ in thickness, which, of course, is correct.

Now, in combined bending and torsion, as the applied loads vary from pure bending to pure torsion, so the thickness of the "lamination of yield" increases (from 0·005 in. to 0·0151 in. for a specimen of 0·1 in. radius in the case of Morrison's tests). This increase in the thickness of the lamination of yield is the cause of the discrepancy between test observations and the maximum shear stress theory.

From Fig. 7 it will be noted that the geometry of yield is vastly different in bending from that in torsion; also, as the combination of stress changes from pure torsion to pure bending so the inclination of the plane of yield changes from right angles to 45 deg. to the centre line of the specimen. At the same time, the geometry of yield is changing from that for pure torsion to that for pure bending. If it is assumed that both these variables are a function of β, the angle of inclination

Fig. 12.



of the plane of yield to the cross-section of the specimen, then t could be calculated from test results and plotted against β as a first trial. It is easily shown that $\beta = \frac{1}{2}\cot^{-1}\alpha$.

Satisfactory test results were not available for tests in combined bending and twisting, and a machine has been designed by the author and manufactured in the engineering workshop of Sheffield University to carry out tests, both static and fatigue, under combined bending and torsion. Space does not allow either the machine or the technique of testing to be dealt with in this paper. Figs. 8 and 9, on this and the opposite pages, show the results of preliminary tests with this machine on mild steel annealed after machining in a high-vacuum furnace. Fig. 8 shows typical load-strain diagrams obtained for various combinations of bending and torsion. The difficulty of locating the yield in pure bending will be noted from the curve for the fourth loading ($\alpha = 0$). Fig. 9 shows the results for various static tests in combined bending and torsion in mild-steel specimens plotted on the usual axes and compared with both the maximum shear strain energy ellipse and the maximum shear stress ellipse. Fig. 10, on this page, shows t plotted against β, and it will be noted that the points lie remarkably well on a straight line.

$$\therefore \text{ in the general case, } t = t_T - \frac{(t_T - t_B)}{45} \cdot \frac{1}{2}\cot^{-1}\alpha,$$

where t_T and t_B are the thicknesses of the laminations of yield in pure torsion and pure bending, respectively.

Considering now the case of a cylinder subjected to internal pressure only, if the internal pressure equals P lb. per square inch, and the external pressure is zero, then, from Lamés equations, we have, for radius $\frac{a_1}{\phi}$,

$$p_R = A + \frac{B}{a_1^2}\phi^2,$$

when

$$\phi = 1; \; p_R = 0$$

$$\phi = K; \; p_R = -P$$

$$\therefore \quad -P = A - \frac{BK^2}{a_1^2}$$

$$0 = A - \frac{B}{a_1^2}.$$

$$\therefore \quad B = \frac{-P a_1^2}{(K^2 - 1)}. \quad . \quad . \quad . \quad (9)$$

$$A = \frac{P}{K^2 - 1}. \quad . \quad . \quad . \quad (10)$$

$$\therefore \quad p_R = \frac{P}{(K^2-1)}(\phi^2 - 1)$$

$$p_T = \frac{P}{(K^2-1)}(\phi^2 + 1) \quad \Bigg\} \quad . \quad . \quad (11)$$

where p_R = radial stress, p_T = tangential stress, p_A = axial stress, a_0 = internal radius, a_1 = external radius, $K = \frac{a_1}{a_0}$, a = any radius between a_0 and a_1, and $\phi = \frac{a_1}{a}$ (ϕ can range from unity to K).

Regarding tension as positive and compression as negative, when $p_T > p_A > p_R$, the maximum shear stress at any radius

$$= \frac{p_T - p_R}{2} = \frac{P\phi^2}{(K^2 - 1)}. \quad . \quad . \quad (12)$$

This will be a maximum when ϕ is a maximum (*i.e.*, $\phi = K$).

$$\therefore \quad q_{max.} = \frac{P K^2}{K^2 - 1}. \quad . \quad . \quad (13)$$

Now let the tensile yield strength $= f_0$ and $q = q_0 = \frac{f_0}{2}$, when $\phi = \psi$.

Then actual shear stress $q_a = \frac{P K^2}{(K^2 - 1)}$ and true shear stress $q_0 = \frac{P\psi^2}{(K^2 - 1)}$.

Correction factor

$$\frac{q_0}{q_a} = \frac{\psi^2}{K^2} = \frac{f_0}{2\,q_a}. \quad . \quad . \quad (14)$$

$$\therefore \quad \text{Permissible shear stress } q_a = \frac{K^2 f_0}{2\psi^2}. \quad . \quad (15)$$

This has assumed that yield does not take place until the shear stress has reached a value $\frac{f_0}{2}$ at a distance t below the inner surface of the tube.

$$\therefore \quad \psi = \frac{a_1}{a_0 + t}$$

$$\therefore \quad \text{from (15) } q_a = \frac{\frac{1}{2}(a_0 + t)^2 f_0}{a_0^2}. \quad . \quad (16)$$

From (14)

$$\frac{q_a}{q_0} = \frac{K^2}{\psi^2} = \frac{(a_0 + t)^2}{(a_0)^2}$$

$$t = a_0\left(\sqrt{\frac{q_a}{q_0}} - 1\right). \quad . \quad . \quad (17)$$

Thus, from test results we know the values of q_a and q_0, hence, for any given test, the value of t may be calculated on the assumption that the maximum shear stress is the criterion of failure. Conversely, should the dimensions of a cylinder be known, and from tests its size and stress effect t and tensile strength f_0 obtained, then the permissible shear stress is calculated from equation (16). Some steels, however, have different yield strengths (f_0) in the longitudinal and transverse directions, and, in the case of thick cylinders, it is important that the correct value for f_0 should be used in calculating t. The plane of maximum shear for a thick cylinder under internal pressure only coincides with the plane of maximum shear for a transverse specimen. Hence it is the transverse yield stress which should be used.

Yield is initiated at the inner surface of the cylinder and the interference it receives from neighbouring crystals is considerable and very complex. Apart from observing that it is probably a function of the internal radius a_0, little may be deduced regarding the effect of size upon t, and only an empirical formula connecting t and a_0 can be deduced from experimental results. A large amount of excellent work has been carried out on thick cylinders subjected to internal pressure by Cook and Robertson.* Cook and Robertson in their tests used specimens having an internal radius of $\frac{1}{8}$ in. and varying values of K; also a longitudinal tensile test was taken from the end of each thick cylinder, thus obviating the effect of non-uniformity of specimens. Unfortunately, it was the longitudinal yield strength which was measured and, as already indicated, it is the transverse yield stress which must be used as a basis of comparison for the maximum shear stress theory. Therefore, their results cannot be used as a basis for calculating t.

Cook, in his experiments, gives both the longitudinal and transverse yield stresses for his steels. He, however, did not take a tensile test for each specimen but gives the mean of 3 to 5 tests. The variations of transverse yield stress for metals A, B and C are 8·4 per cent., 11·65 per cent., and 3·7 per cent., respectively. These variations must be borne in mind when studying the variations in the value of t calculated below. It is assumed that the maximum shear stress theory is correct, and from Cook's results for metals A, B, C, the value of t is calculated. For metal A there are three sets of tests. In each set the internal radius remains constant (0·156 in., 0·111 in. and 0·0635 in., respectively), while the value of K is varied. For metals B and C the value of K is kept constant (K = 3) and the internal radius (a_0) varied. No effort is made to develop a theory showing how t varies with a_0, but as a first trial, in Fig. 11, page 287, t is plotted against a_0, and it will be seen that the points lie well on a straight line.

It will be noted that not only does the value of t for any given radius a_0 depend upon the properties of the metal, but also the rate of increase of t with a_0 varies from one metal to another. Since, however, the variation in the rate of increase of t with a_0 is small, in the opinion of the author the mean value for metals A, B and C may be taken, as a first approximation, as applying to all metals having a plastic yield. Thus, if we write $t = A + B\,a_0$ we get $t = A + 0{\cdot}054\,a_0$. The value of A must be found by experiment on a thick cylinder of known transverse tensile yield strength.

At the inner surface $\frac{\delta q}{\delta a} = \frac{-f_0}{a_0}$ approximately.

$$= \frac{-2q_0}{a_0} \text{ approximately.}$$

Now at the condition of yield $\delta a = t$ and $\delta q =$ the error in estimating the true yield strength.

$$\therefore \quad \frac{q\delta}{t} = \frac{-2\,q_0}{a_0}.$$

$$\therefore \text{ percentage error } = \frac{\delta q}{q_0} \times \frac{100}{1} = \frac{2\,t}{a_0} \times \frac{100}{1}.$$

But

$$t = A + 0{\cdot}054\,a_0$$

$$\therefore \text{ percentage error } = \left(\frac{A + 0{\cdot}054\,a_0}{a_0}\right) \times 200.$$

Thus, the larger the value of a_0 the smaller will the percentage error be, but even if a_0 were infinity the percentage error would still be 10·8. It follows, then, that if an accuracy greater than 10 per cent. is required in thick cylinders, correction must always be made for size effect if the design is to be based on the tensile yield strength, taking $f_0 = 2q_0$.

* G. Cook and A. Robertson. ENGINEERING, vol. 92, page 786 (1911).

Up to the present, only the upper yield strength of mild steel has been discussed. To many engineers this strength is considered irrelevant, it being maintained that the residual stresses, stress concentrations, and manufacturing strains are such that the conditions for producing the upper yield cannot be realised in practice. In view of this, some attention has been devoted to the lower yield strength of mild steel when subjected to combined bending and twisting. Fig. 8 actually represents a series of such tests, while the upper curve in Fig. 9 is the result of a number of such tests. Fig. 12, page 287, applies to torsion only and shows the size effect and stress-distribution effect for specimens of various diameters relative to both upper and lower yield stress ratios. Morrison did not estimate the lower yield stress in any of his torsion tests and the values used were read from diagrams. The results of the author's preliminary tests are shown by the full line. It will be noted that the stress-distribution effect is much greater when referred to the lower yield stress, but that the size effect is not so great.

From the results of Moore and Morkovin* the size effect in fatigue seems more pronounced than that for a static test, when the lower yield strengths are used. It may be that fatigue strengths are more closely related to the upper yield strengths than the lower. If this is the case, then the upper yield strength is not irrelevant.

In Figs. 3, 5, 6, 10 and 11, empirical relationships are derived for the relationship between t, the dimensions of the specimen, and the mode of stressing. In Fig. 5 it is shown that t is not affected by the stress gradient, and therefore it follows that the relationship between t and diameter of specimen for pure torsion, given by Fig. 3, must be due to the geometry of yield only. Fig. 6 demonstrates that, for pure bending, within the limits of experimental accuracy, t is independent of the diameter of the specimen, being a constant of the material. That in combined bending and twisting there should be a simple relationship between t and β (Fig. 10) is not easy to understand. Of course, the simple relationship between radius of specimen and t for pure torsion is equally surprising. These relationships may be only fortuitous and have little fundamental significance, but it seems evident that, for a better understanding of the process of yield, the geometry of yield under the various combinations of stressing must be examined in more detail than has been the case in the past.

Let it be supposed that a part, of diameter D, is required to work under a condition of compound stress where the ratio torque : bending moment equals α. Let tensile, torsion and bending tests be carried out on specimens of diameter d and the respective yield stresses obtained be f_0, q_a and f_b.

$$\left.\begin{aligned} \text{Then, for torsion } t_T &= \left(1 - \frac{f_0}{2\,q_a}\right)\frac{d}{2} \\ \text{and for bending } \quad t_B &= \left(1 - \frac{f_0}{f_b}\right)\frac{d}{2} \end{aligned}\right\} \text{ for specimens.} \quad (18)$$

$$\text{From Fig. 3} \qquad t = A - \frac{0{\cdot}00067}{R}. \quad . \quad (19)$$

The constant 0·00067 is assumed to be due to the geometry of yield, and not a function of the material.

$$= t_T - 0{\cdot}00067\,\frac{(D - d)}{D\,d} \times 2 \quad . \quad (20)$$

and for combined stress (t_α)

$$= \frac{t_a - t_B}{45}\left(\tfrac{1}{2}\cot^{-1}\alpha\right). \quad . \quad . \quad (21)$$

Then the allowable working stress (*i.e.*, maximum shear stress)

$$= \frac{f_0}{2}\,\frac{D}{D - 2\,t_\alpha}. \quad . \quad . \quad . \quad . \quad (22)$$

In thick cylinders it is not surprising that t depends only upon a_0, but it is remarkable that the relationship should be so simple.

The conclusions reached from the above work are as follows.

(A) If the upper yield strength is used as a basis of design, then for tests in pure torsion the specimens should have a diameter of not less than 1 in. if the actual structure is greater than 1 in. in diameter. If a specimen of smaller diameter is used, then correction should be made for size effect; otherwise the test results will give an apparent strength which will be superior to that which will be realised in the actual structure. In tests in pure bending for parts of a structure greater than $\frac{1}{2}$ in. in diameter, the diameter of the specimen should not be less than $\frac{1}{2}$ in. unless a correction factor for size effect is used. In combined bending and torsion, or combined direct stress and torsion, tests relative to machine parts greater than 1 in. in diameter should use specimens not less than 1 in. diameter unless a correction factor is used.

(B) If the lower yield stress is used as a basis of design, then size effect is small, but there is a large stress-distribution effect (*i.e.*, t is large but not greatly affected by size of specimen). Note the curves for the lower yield stress in Figs. 9 and 12. Thus, for lower yield stresses, smaller specimens could be used in bending or torsion without applying a correction factor.

(C) It seems probable that t depends upon the size of crystals in the metal. The larger the crystals the greater the value of t, and therefore the greater will the corresponding bending or torsion strengths exceed the tensile strength. It follows then, that for the bending or torsion of small rods and wires, such as are used in helical springs, the optimum grain size may be somewhat larger than that which gives maximum tensile strength.

(D) In thick cylinders, the value of t for a given material depends upon the bore of the cylinder only. Size effect, however, is always present, and when the test cylinder differs greatly from the actual cylinder, correction must be made for size effect.

(E) The value of the lamination of yield t is independent of the stress gradient and seems to be connected mainly with the geometry of yield.

(F) For parts which are to withstand static combined bending and twisting stresses, the tensile, pure-torsion and pure-bending tests represent the minimum required, if the strength of the part is to be known accurately.

The author wishes to express his thanks to Professor H. W. Swift, D.Sc., Professor Morrison, D.Sc., and Mr. J. Andrew, B.Sc.

* H. F. Moore and D. Morkovin. *Proc. A.S.T.M.*, vol. 44, page 137 (1944)

CATALOGUES.

Protective Gloves.—Messrs. Firkins and Company, Limited, Worcester, have issued a leaflet illustrating some typical examples of the several hundred different types of gloves which they manufacture in various materials for protective purposes in a wide range of industries.

Milling Cutters.—Messrs. Protoute, Limited, Central House, Upper Woburn-place, London, W.C.1, have sent us a copy of their publication describing "Prolite-Nurake" milling cutters for machining steel, cast iron and light alloys. The cutters are of the solid and the inserted-tooth types.

Pig Iron, Castings and Lead-Lined Plant.—A pamphlet issued by Messrs. M. and W. Grazebrook, Limited, Dudley, Worcestershire, contains a brief history of the firm and some particulars of their products, which include cold-blast pig iron, grey-iron castings, steel fabrications, and homogeneous lead-lined tanks, pans, digesters and other equipment.

Air Compressors.—A publication issued by the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, describes their range of air-compressor equipment, type AC. The series, from type AC1 to AC5, provides for working pressures from 250 lb. to 600 lb. per square inch, and capacities from 7·1 to 17·5 cub. ft. of free air per minute.

Interval-Timing Clock.—Messrs. Turner Manufacturing Company, Limited, Wulfruna Works, Villiers-street, Wolverhampton, have sent us a leaflet describing an instrument known as an interval timer, for giving a visual signal on the completion of any time interval from a few seconds to 15 minutes. The instrument is made for either wall or panel mounting, and is operated by a synchronous motor on 200/250-volt single-phase 50-cycle circuits.

Casting Alloys in Aluminium, Magnesium and Zinc.—Messrs. Birmingham Aluminium Casting (1903) Company, Limited, Birmid Works, Dartmouth-road, Smethwick, 40, Staffordshire, have sent us a copy of the Birmal data book and "Guide to the Selection of Suitable Casting Alloys in Aluminium, Magnesium and Zinc." Data on alloys for sand casting, gravity die casting and pressure die casting are given, and photographs of typical castings are reproduced.

Diesel Engines.—We have received from the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, a booklet, Publication DE/107, describing and illustrating in considerable detail their Type L Diesel engines. The engines are manufactured in four sizes running at either 375 r.p.m. or 428 r.p.m., and either naturally-aspirated or pressure-charged. The output varies over a wide range from 625 brake horse-power to 1,716 brake horse-power.

Scientific Apparatus.—Messrs. Griffin and Tatlock, Limited, Kemble-street, Kingsway, London, W.C.2, have sent us a copy of their new 600-page bound catalogue, No. 52 AB, of scientific apparatus. The catalogue is compiled primarily for use in educational laboratories and covers apparatus needed in the study of physics, chemistry, biology and general science leading to university and other examinations. Numerous illustrations and detailed descriptions of apparatus are included.